



BY APPOINTMENT TO  
HER MAJESTY QUEEN ELIZABETH II  
MANUFACTURERS OF DAIMLER AND JAGUAR CARS  
JAGUAR CARS LIMITED COVENTRY



BY APPOINTMENT TO  
HER MAJESTY QUEEN ELIZABETH  
THE QUEEN MOTHER  
MANUFACTURERS OF DAIMLER AND JAGUAR CARS  
JAGUAR CARS LIMITED COVENTRY



BY APPOINTMENT TO  
HIS ROYAL HIGHNESS THE PRINCE OF WALES  
MANUFACTURERS OF DAIMLER AND JAGUAR CARS  
JAGUAR CARS LIMITED COVENTRY



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## Technical Guide

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# AJ-V8 Engine and 5HP24 Transmission Introduction

This Technical Guide introduces the new AJ V8 engine and 5HP24 transmission installed in the XK8 Sports car. It is intended to give Jaguar Dealer workshop personnel an overview of their construction and operation, and is for information purposes only. The contents of this Technical Guide must not be used as a reference source for servicing procedures; all servicing procedures must be in accordance with the appropriate Service Manual.

This Technical Guide will not be updated. While every effort is made to ensure accuracy, changes may occur between going to press and the equipment being introduced to the market. Once the equipment is in service, details of changes can be obtained from Service Bulletins and revisions to the Service Manuals.

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The following abbreviations are used in this document:

<b>Abbreviation</b>	<b>Description</b>
ABS	anti-lock braking system
A/C	air conditioning
A/CCM	air conditioning control module
BPM	body processor module
BHP	brake horse power
°C	degree Celsius
CAN	controller area network
CDI	cubic inch displacement
DIN	Deutsche Institut für Normung
dc	direct current
DTC	diagnostic trouble code
ECM	engine control module
ECT	engine coolant temperature
EGR	exhaust gas recirculation
EMS	engine management system
EVAP	evaporative emission
°F	degree Fahrenheit
ft	foot
HO2S	heated oxygen sensor
in	inch
JDS	Jaguar diagnostic system
lb	pound
lbf.ft	pound force feet
kg	kilogram
km/h	kilometer per hour
kW	kilowatt
m	meter
MAFS	mass air flow sensor
MIL	malfunction indicator lamp
mph	miles per hour
mm	millimeter
ms	millisecond
Nm	Newton meter
NOx	nitrous oxide
OBD	on-board diagnostics
O2S	oxygen sensor
PAS	power assisted steering
PDU	portable diagnostic unit
psi	pounds per square inch
PTFE	polytetrafluoroethane
rpm	revolutions per minute
SAE	Society of Automotive Engineers (USA)
SCP	standard corporate protocol
TCM	transmission control module
USA	United States of America
V	volt
VSV	vacuum solenoid valve

The AJ-V8 4.0 litre, engine is the first of a new family of Jaguar engines. Designed to give excellent performance, refinement, economy and low vibration levels it also conforms to the strictest emission legislation. Weighing only 200 kilograms (441 lb), the engine is shorter by 12 inches (300 mm) than the current AJ16 4.0 litre engine. Compression ratio is 10.75:1, with four valves per cylinder. The cylinder heads, block and bedplate are all cast aluminum. Cylinders have electro-plated bores which reduce piston friction, improve warm-up and oil retention. A variable valve timing system has been introduced to give improved low and high-speed engine performance and excellent idle quality. The valve gear is chain driven for durability. Low valve overlap improves engine idle speed and low residual fuel levels which improves combustion and reduces hydrocarbon emissions. The inlet manifold is a one-piece, composite moulding with integral fuel rails connecting to the eight side feed fuel injectors. Air flow into the engine is via an electronic throttle assembly. Movement of the throttle is controlled by sensors in the throttle assembly through the ECM. The engine has a low volume, high velocity, cooling system which achieves a very fast warm-up with reduced and even metal temperatures in the combustion chamber and increased bore temperatures.

The generator, A/C pump, and PAS pump are mounted to the cylinder block on rigid cradle supports. Accessory drive is from a single, 7-ribbed vee belt. Hydraulic engine mounts minimise noise and vibration.

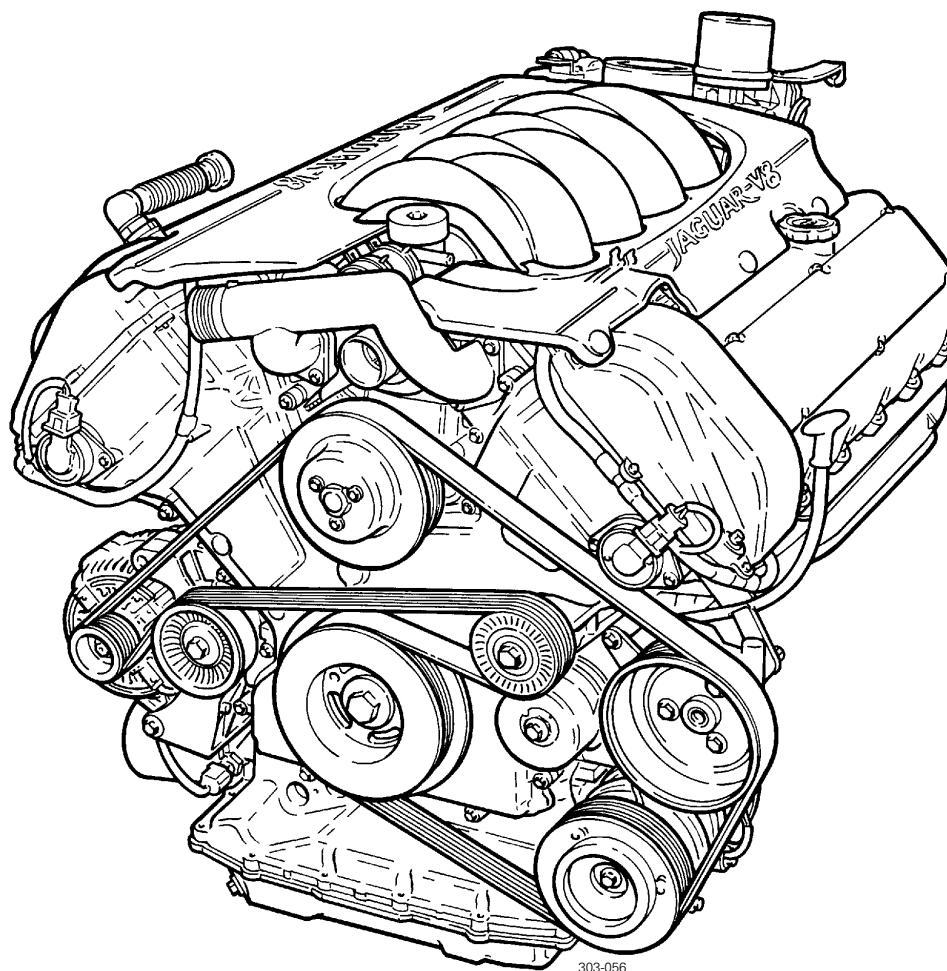
A new engine management system adjusts fuel and ignition settings, monitors and controls exhaust emissions and provides an on-board diagnostic capability.

The transmission is a new ZF 5-speed, automatic, electronically controlled unit.

The unit is oil filled for life so does not have an oil gauge (dipstick). Two driver selected modes are available, sport or normal. The TCM is programmed with cruise, traction, gradient, warm-up and hot mode features. It also provides an on-board diagnostic capability.

The engine and transmission meet OBDII USA environmental regulations. Default limp home modes for both engine and transmission are provided.



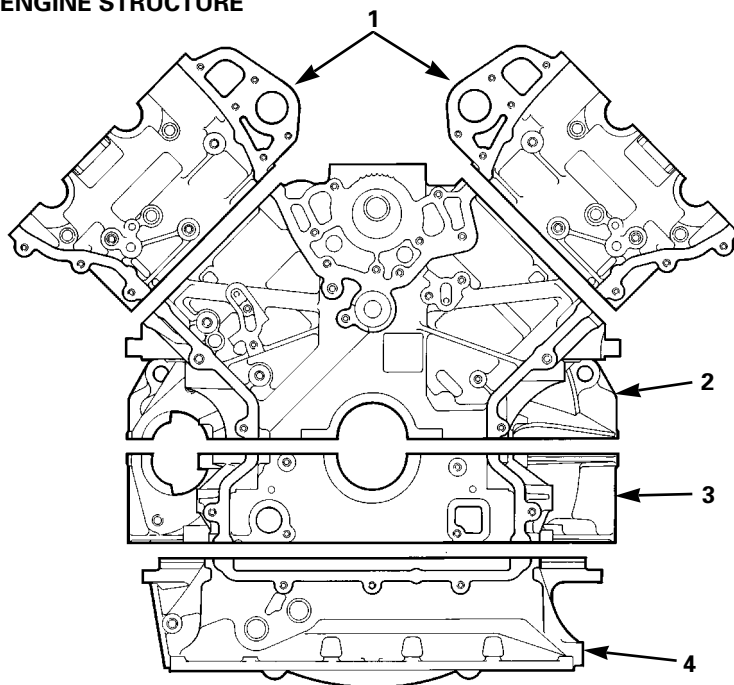


## Basic Engine

The AJ-V8 is an all new 90° V8 liquid cooled engine that gives refined and effortless performance. Constructed in aluminum alloy, the AJ-V8 introduces several innovative design features new to Jaguar engines, the most notable of these being:

- a bedplate
- nikasil coated cylinder bores
- fracture split connecting rods
- variable valve timing
- aluminum alloy valve lifters
- electronic throttle control.

## ENGINE STRUCTURE



- |                   |                    |
|-------------------|--------------------|
| 1. Cylinder Head  | 3. Bed Plate       |
| 2. Cylinder Block | 4. Structural Sump |

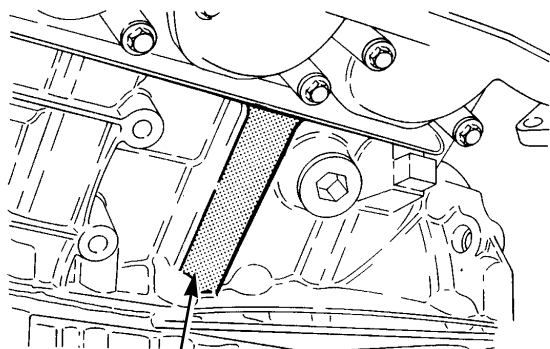
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## Cylinder Block

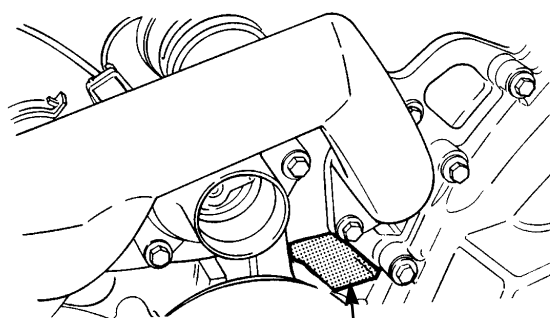
The cylinder block is an "enclosed V" design, which provides an inherently rigid structure with good vibration levels. Nikasil (a composition of nickel and silicon) coated cylinder bores provide good friction, heat transfer and piston noise levels. A low volume coolant jacket improves warm-up times and piston noise levels; the longitudinal flow design of the jacket, with a single cylinder head coolant transfer port in each bank, improves rigidity and head gasket sealing. The right hand cylinder bank is designated as "A" bank, and the left hand as "B" bank. The cylinder bores of each bank are numbered from 1 to 4, starting from the front.

Engine data is marked at three locations on the cylinder block. Component diameters are represented by alphabetical and numerical codes; keys to the codes are in the Service Manual.

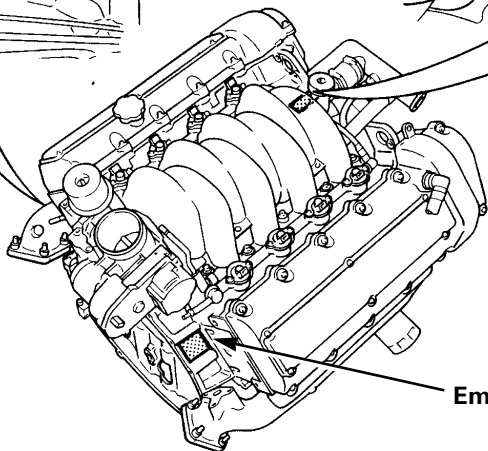
## ENGINE DATA LOCATIONS



\* Main Bearing Crankshaft  
Diameters \* Connecting  
Rod Bearing Crankshaft  
Diameters \* Cylinder Bore  
Diameters \* Main Bearing  
Bore Diameters \*



Serial Number



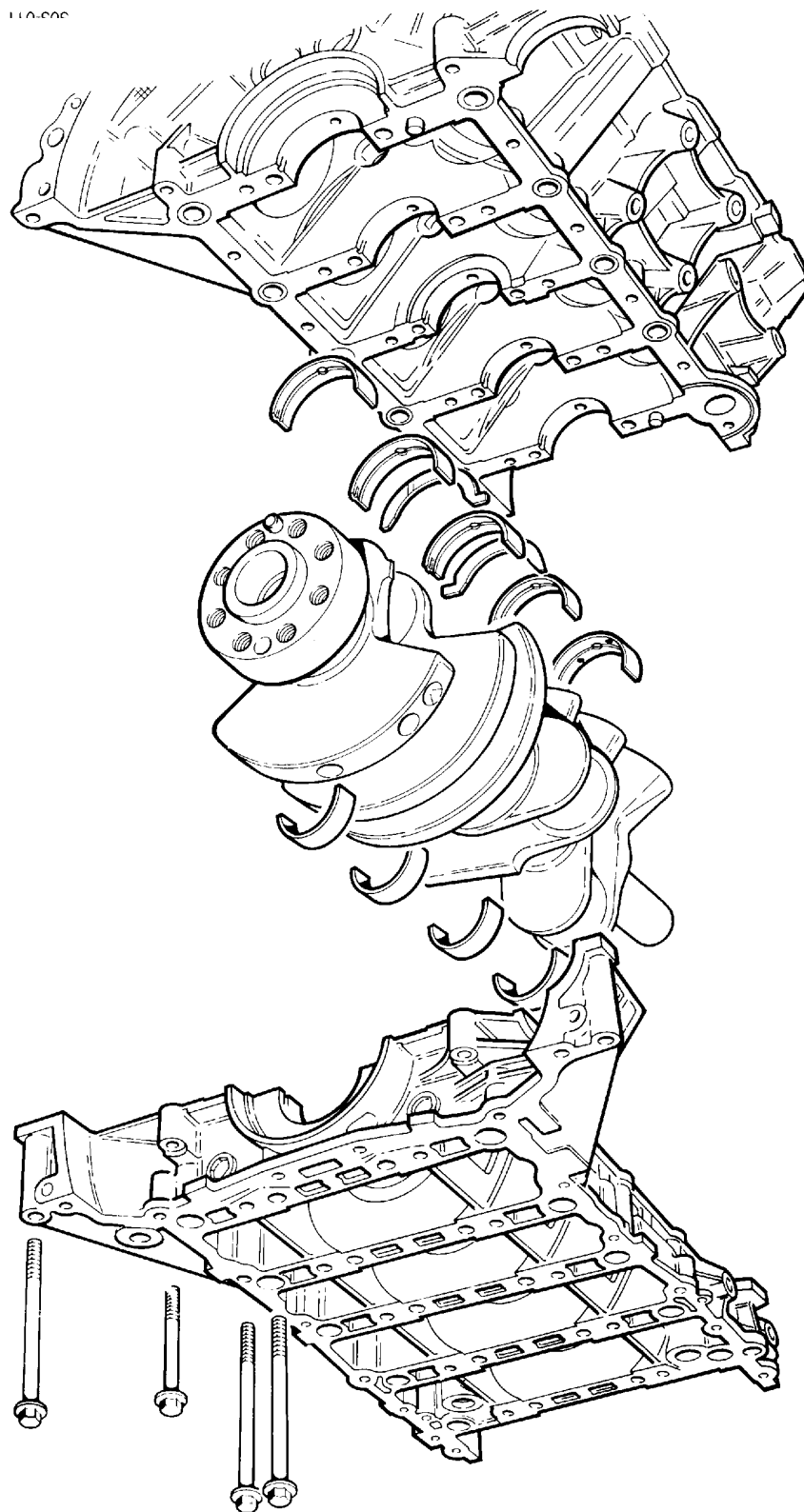
Emissions Code

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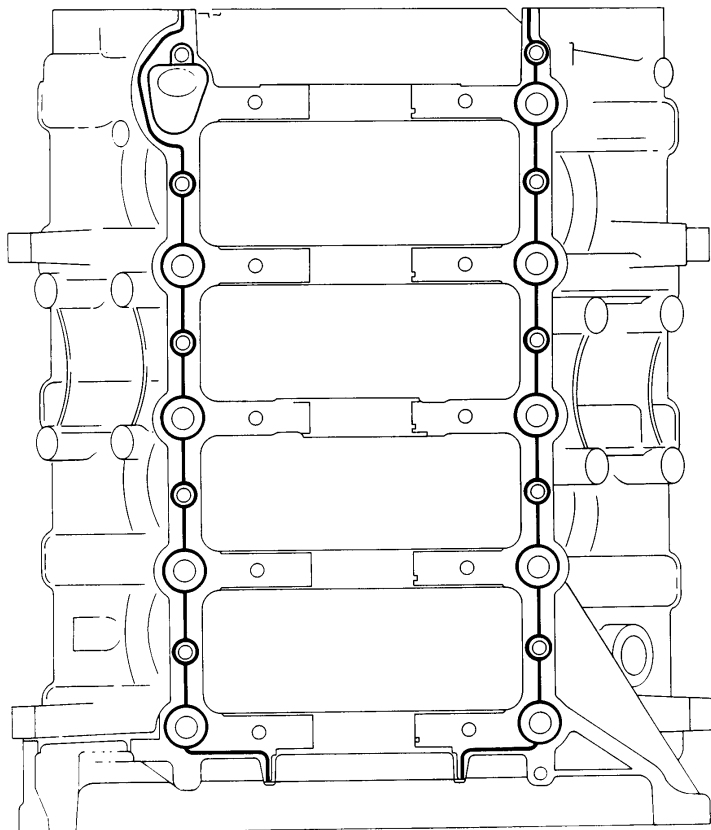


CYLINDER BLOCK, CRANKSHAFT AND BEDPLATE

110-006



303-011

**SEALANT TRACK ON BEDPLATE**

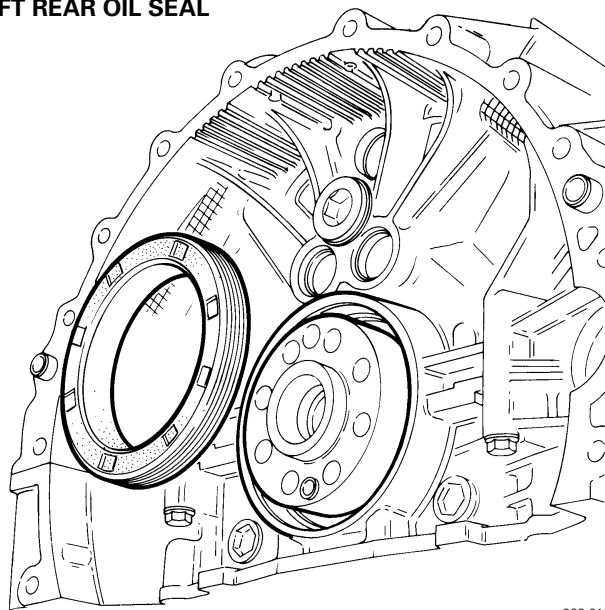
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**Bedplate**

The bedplate is a structural casting bolted to the bottom of the cylinder block to retain the crankshaft. The use of a bedplate further improves rigidity. Iron inserts, cast into the main bearing supports of the bedplate, minimise main bearing clearance changes due to heat expansion.

Two hollow dowels align the bedplate with the cylinder block.

Beads of sealant seal the joint between the bedplate and the cylinder block.

**CRANKSHAFT REAR OIL SEAL**

303-013

**Crankshaft**

Six counter-balance weights ensure good vibration levels from the four throw, five bearing crankshaft. Manufactured in cast iron, the crankshaft also has undercut and rolled fillets for improved strength.

The main bearings are aluminum/tin split plain bearings. An oil groove in the top half of each bearing transfers oil into the crankshaft for lubrication of the connecting rod bearings. A lead/bronze thrust washer is installed each side of the top half of the center main bearing.

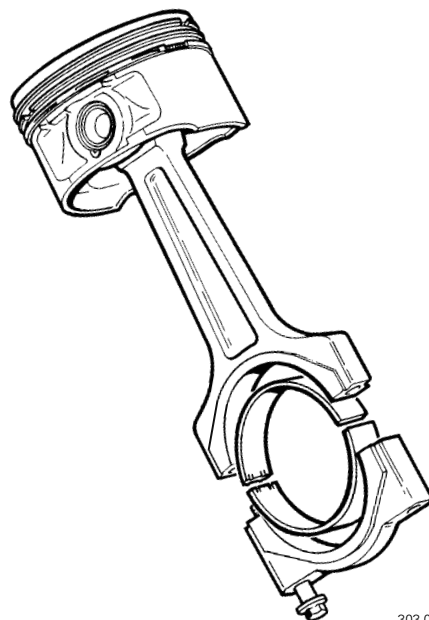
The crankshaft rear oil seal (a lip seal similar to that used on the AJ16 engine) is a press fit in the bedplate to cylinder block interface.

## Connecting Rods and Pistons

The connecting rods are manufactured in sinter forged steel. The bearing caps are produced by fracturing the opposing sides of the connecting rod at the bearing horizontal center-line. As well as being easier to manufacture, when re-assembled the fractured surfaces interlock to form a strong seamless joint. The cylinder position is etched on adjoining sides of the joint to identify matching connecting rods and bearing caps. The connecting rod bearings are lead/bronze split plain bearings.

The pistons are of the open ended skirt design with flat upper surfaces to reduce heat absorbption. Three piston rings, two compression and one oil control, are installed on each piston. Each piston is installed on a wrist pin located in a lead/bronze bushing in the connecting rod.

**CONNECTING ROD AND PISTON**

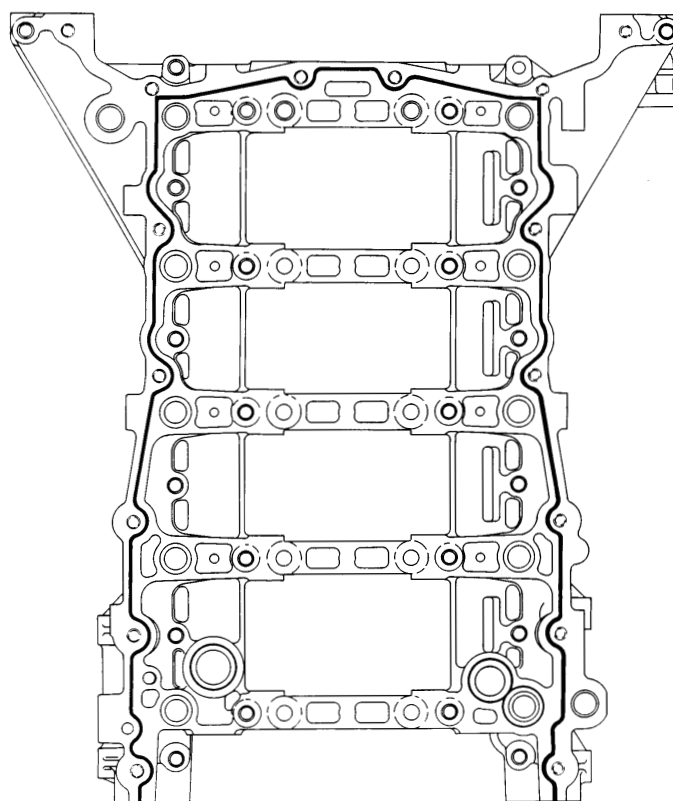


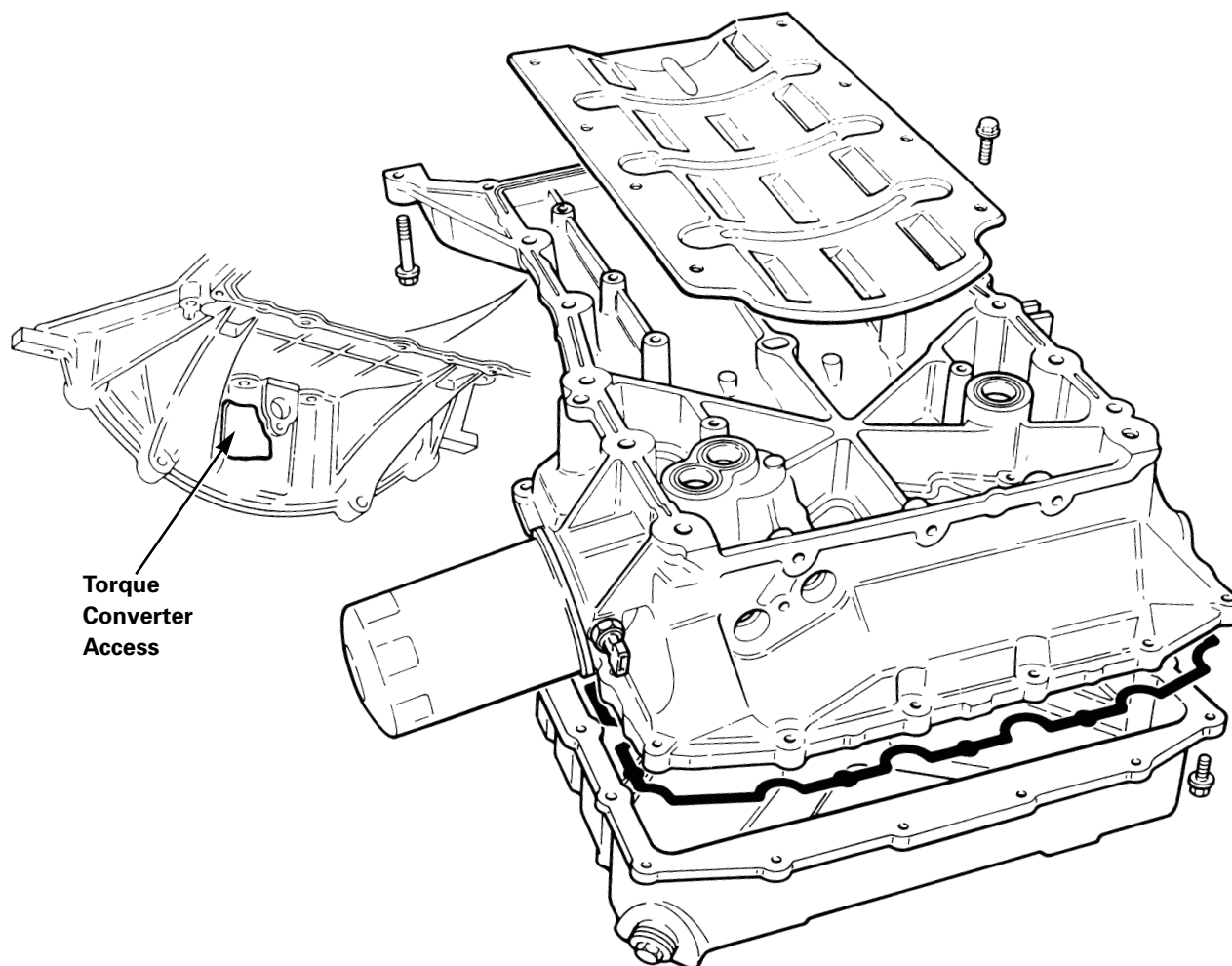
## Sump

The sump consists of an aluminum alloy structural sump bolted to the bedplate, and a pressed steel oil pan bolted to the structural sump. A windage tray attached to the top of the structural sump isolates the oil pan from the disturbed air produced by the rotation of the crankshaft, to prevent oil aeration and improve oil drainage. A rubber plug at the rear of the structural sump seals the port that provides access to the torque converter securing bolts. The engine oil drain plug is located at the front right corner of the oil pan.

A silicon rubber in-groove gasket seals the joint between the oil pan and the structural sump; a bead of sealant seals the joint between the structural sump and the bedplate.

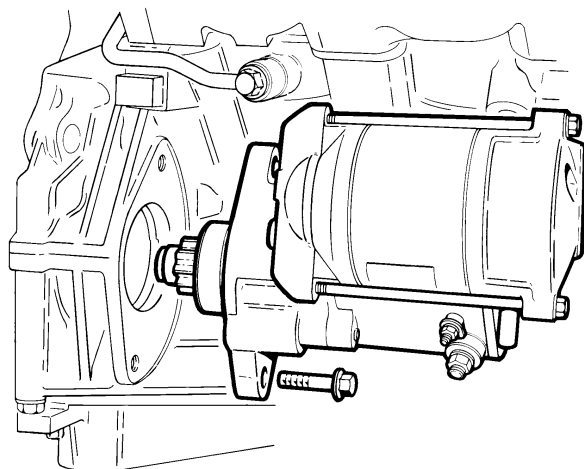
**SEALANT TRACK ON STRUCTURAL SUMP**



**STRUCTURAL SUMP AND OIL PAN**

Torque  
Converter  
Access

303-010

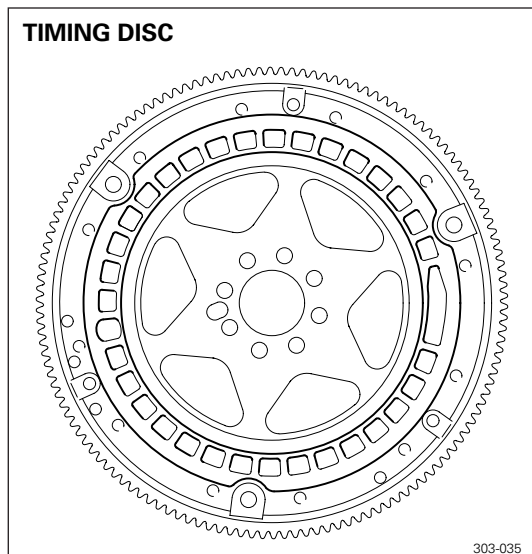
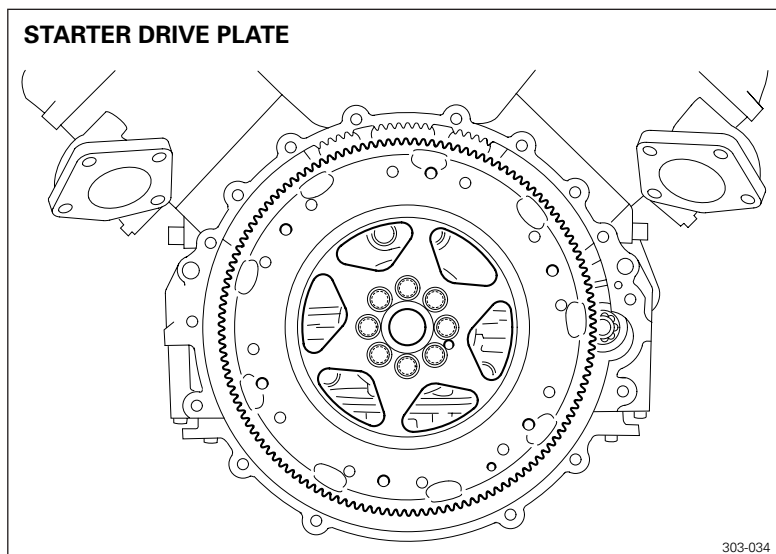
**STARTER MOTOR**

303-062

**Starter and Drive Plate**

The engine starter motor is installed at the rear right side of the engine, at the cylinder block to bedplate split line (for further details of the starter motor see Technical Guide, XK8 Introduction).

The starter drive plate is attached to the rear of the crankshaft. A timing disc, for the engine speed sensor, is spot welded to the front face of the drive plate.

**TIMING DISC**

**STARTER DRIVE PLATE**


## Cylinder Heads

The cylinder heads are unique to each cylinder bank. Deep seated bolts, to reduce distortion, secure the cylinder heads to the cylinder block. Two hollow dowels align each cylinder head with the cylinder block.

The cylinder head gaskets consist of a silicon beaded composite gasket with metal eyelets for the cylinder bores, similar to that on the AJ16 engine.

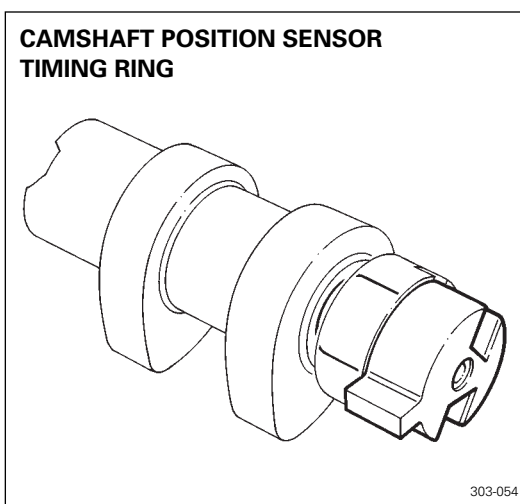
Each cylinder head incorporates dual overhead camshafts operating four valves per cylinder via solid aluminum alloy valve lifters. Steel shims in the top of the valve lifters enable adjustment of valve clearances.

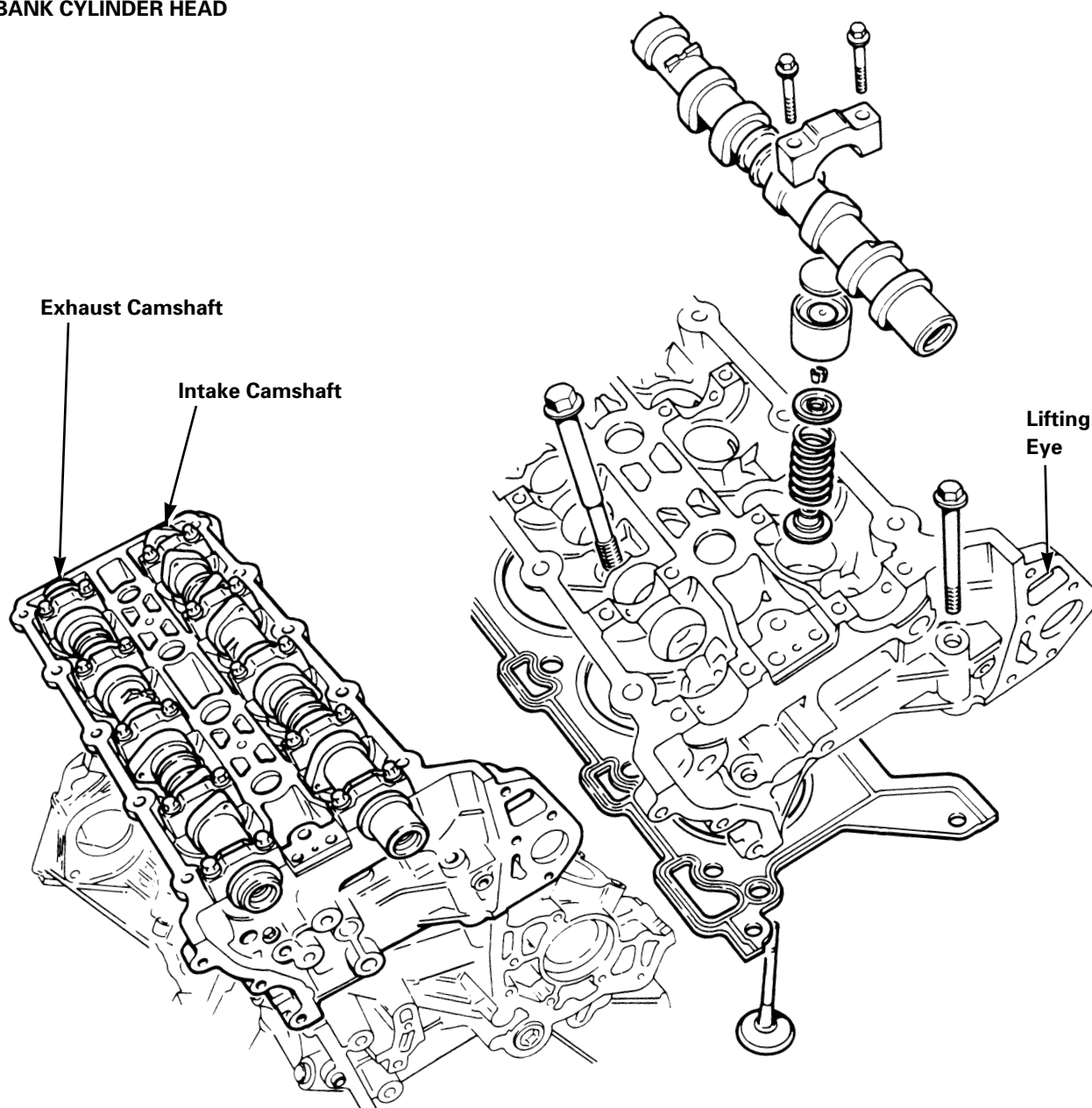
The lightweight valve gear provides good economy and noise levels. Valve head diameters are 31mm (1.220 in) for the exhaust and 35mm (1.378 in) for the intake. All valves have 5mm (0.197 in) diameter stems supported in sintered metal seats and guide inserts. Collets, valve collars and spring seats locate single valve springs on both intake and exhaust valves. Valve stem seals are integrated into the spring seats.

The camshafts are manufactured in chilled cast iron. Five aluminum alloy caps retain each camshaft. Location numbers, 0 to 4 for the intake camshaft and 5 to 9 for the exhaust camshaft, are marked on the outer faces of the caps. The rear of B bank intake camshaft has a timing ring for the camshaft position sensor. A flat, machined near the front of each camshaft, enables the camshafts to be locked during the valve timing procedure.

The 14 mm spark plugs, one per cylinder, locate in recesses down the center-line of each cylinder head.

An engine lifting eye is cast into the front of each cylinder head (the rear lifting eyes, one on each cylinder head, are bolt-on tools).

**CAMSHAFT POSITION SENSOR  
TIMING RING**


**A BANK CYLINDER HEAD**

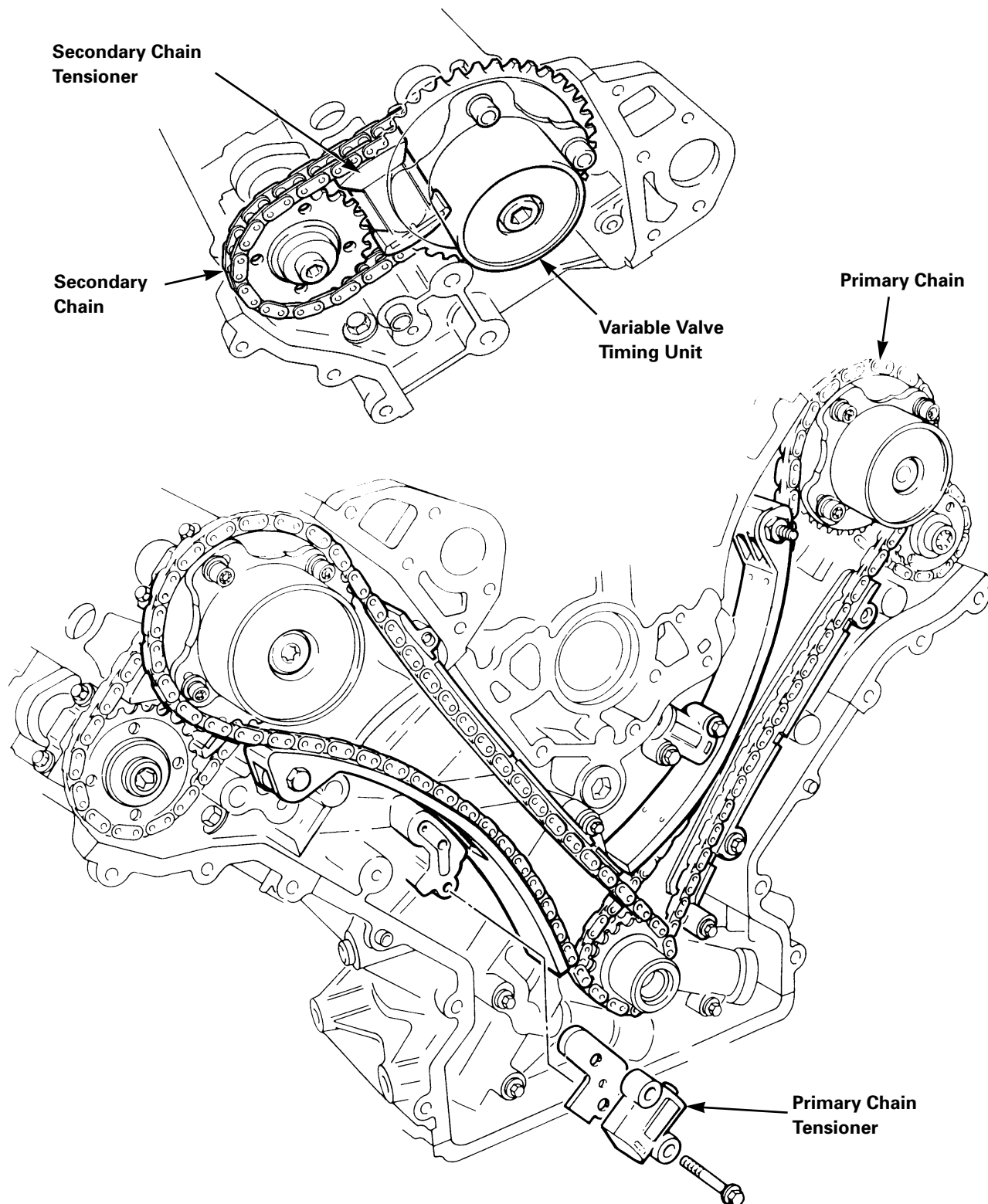
303-047

**Timing Gear**

Single row primary and secondary chains drive the camshafts of each cylinder bank. The primary chains transmit the drive from two sprockets on the crankshaft to variable valve timing units on the intake camshafts. The secondary chains transmit the drive from the variable valve timing units to sprockets on the exhaust camshafts.

(Continued on Page 14)

**TIMING GEAR**



303-016 / 017

**Timing Gear (Continued)**

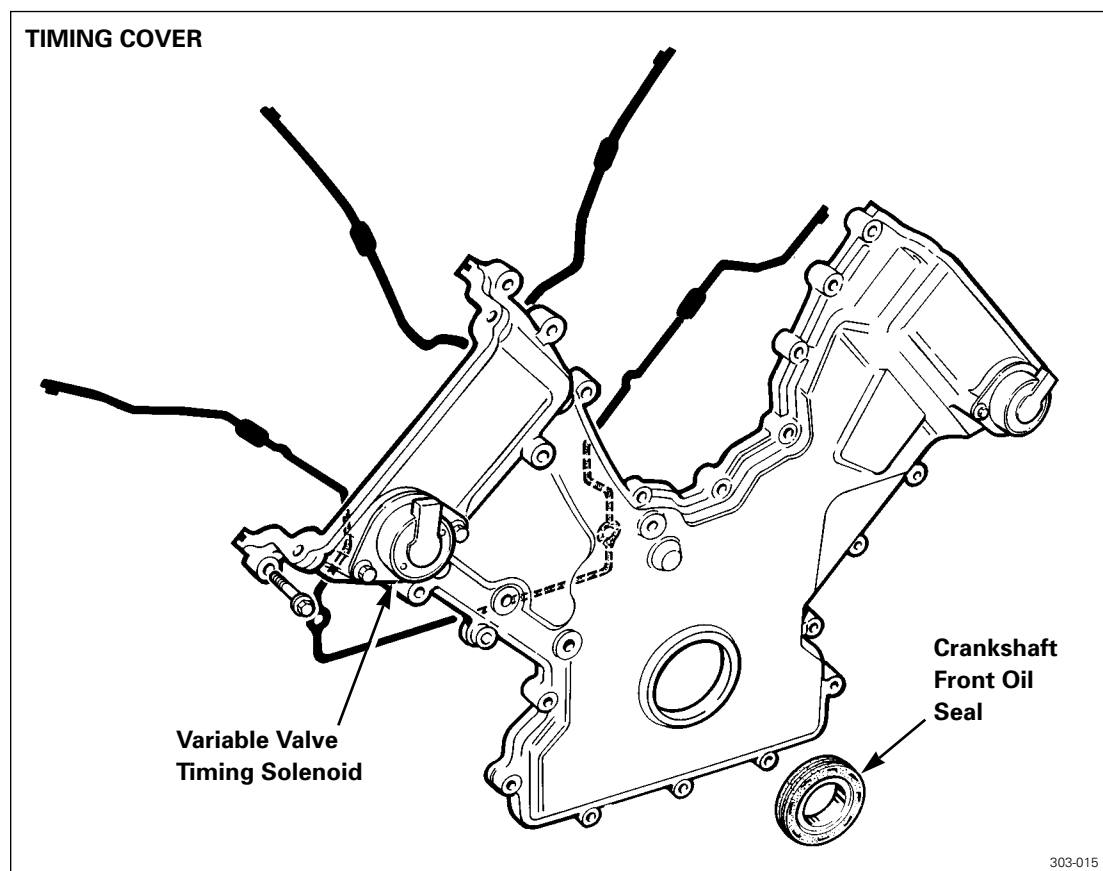
A key locates the two drive sprockets on the crankshaft. The crankshaft's torsional vibration damper retains the sprockets in position.

The variable valve timing units and the exhaust camshaft sprockets are non-interference, non-keyed fits on their respective camshafts; the drive being transmitted by the face to face friction load produced by the valve timing unit/sprocket securing bolt.

Each chain has an hydraulic tensioner operated by engine oil. A jet of oil from the end of each tensioner lubricates the chains. The primary chain tensioners act on pivoting flexible tensioner blades. The secondary chain tensioners act directly on the chains. Guide rails are installed on the drive side of the primary chains.

**Timing Cover**

The aluminum alloy timing cover accommodates the crankshaft front oil seal (a PTFE lip seal) and the two variable valve timing solenoids. Silicon rubber in-groove gaskets seal the joint between the timing cover and the front face of the engine.



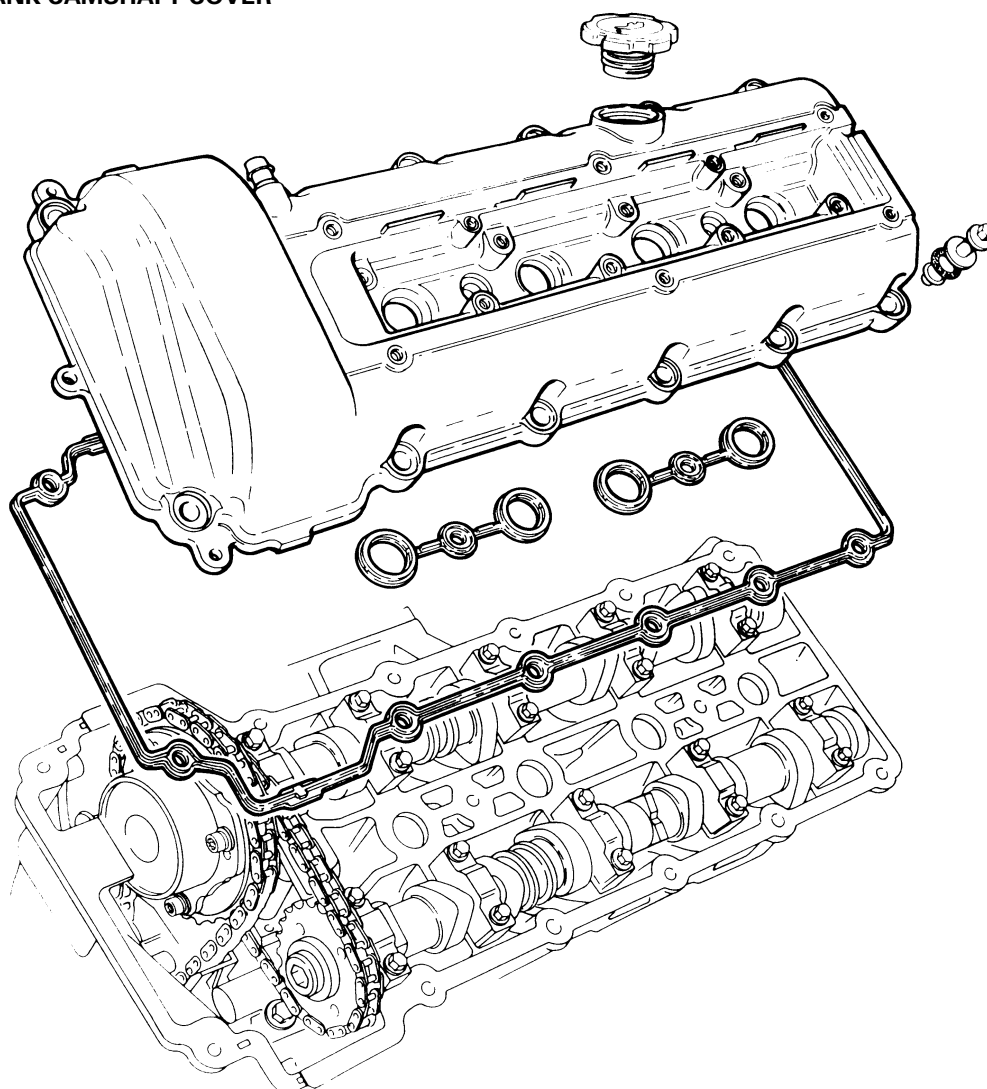


## Camshaft Covers

The camshaft covers are manufactured from vinyl ester composite. The A bank camshaft cover incorporates an outlet for the full load engine breather. The B bank camshaft cover incorporates the engine oil filler cap and an outlet for the part load engine breather. Identical oil separators are incorporated below the breather outlet in each cover (see Crankcase Ventilation, page 35).

Silicon rubber in-groove gaskets seal the joints between the camshaft covers and the cylinder heads. Together with spacers and seals on the camshaft cover fasteners, they also isolate the covers from direct contact with the cylinder heads, to reduce noise.

### B BANK CAMSHAFT COVER



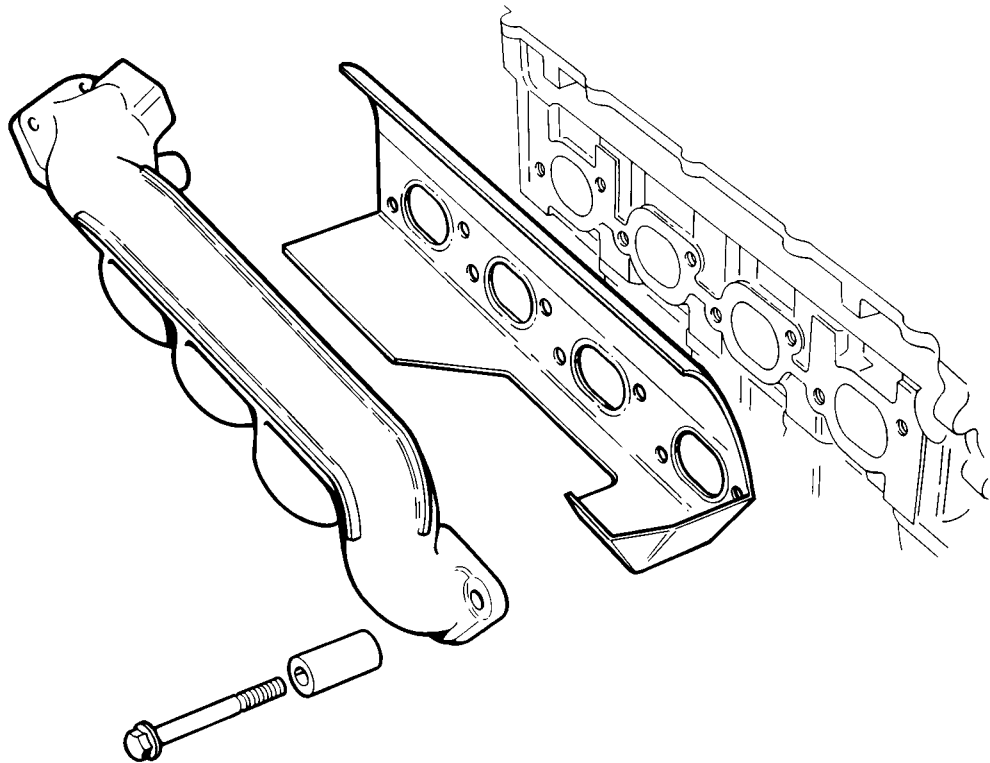
303-042

**Exhaust Manifold**

The thin-wall cast iron manifolds are unique for each cylinder bank. On engines with EGR, the A bank manifold has a connection for the transfer pipe.

Spacers on the securing bolts allow the manifolds to expand and retract with changes of temperature while maintaining the clamping loads.

Heat shields are integrated into the exhaust manifold gaskets.

**EXHAUST MANIFOLD**

303-023

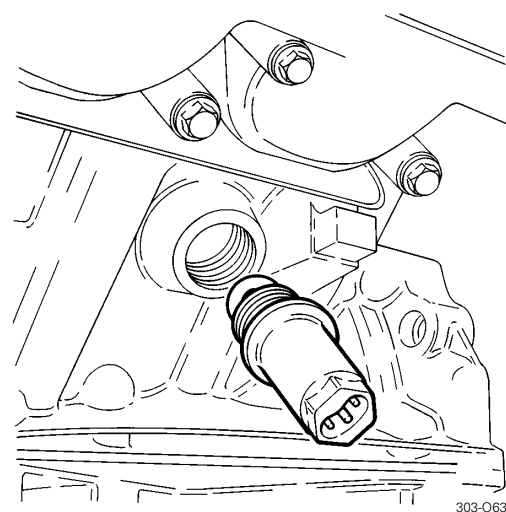
## Engine Cooling

The cooling system is a low volume, high velocity system with good warm-up and temperature profile characteristics.

From the pump, the coolant flows into each bank of the cylinder block. In each bank, 50% of the coolant cools the cylinder bores and 50% is diverted through a bypass gallery. At the rear of the banks the two flows mix and enter the cylinder heads. The coolant then flows forwards to the outlet ports. When the thermostat is closed, the coolant returns directly to the pump through the bypass on the thermostat housing. When the thermostat is open, the coolant returns to the pump via the vehicle's radiator.

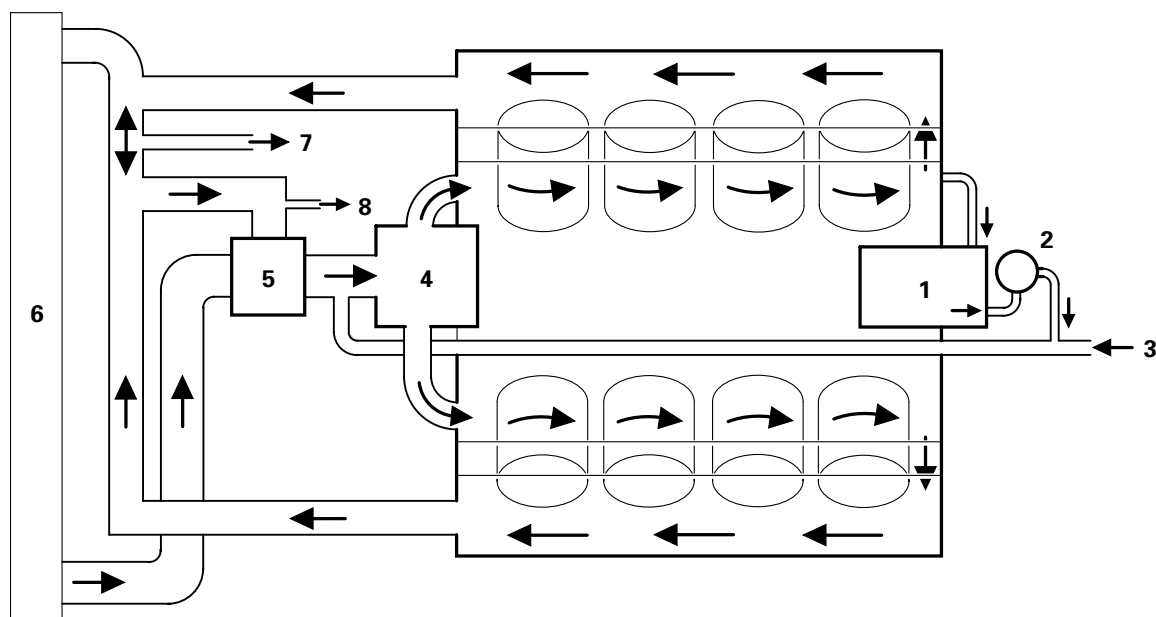
A coolant drain plug is installed on the rear left side of the cylinder block. On vehicles with the cold climate package, the cylinder block heater replaces the drain plug.

**CYLINDER BLOCK DRAIN/HEATER**



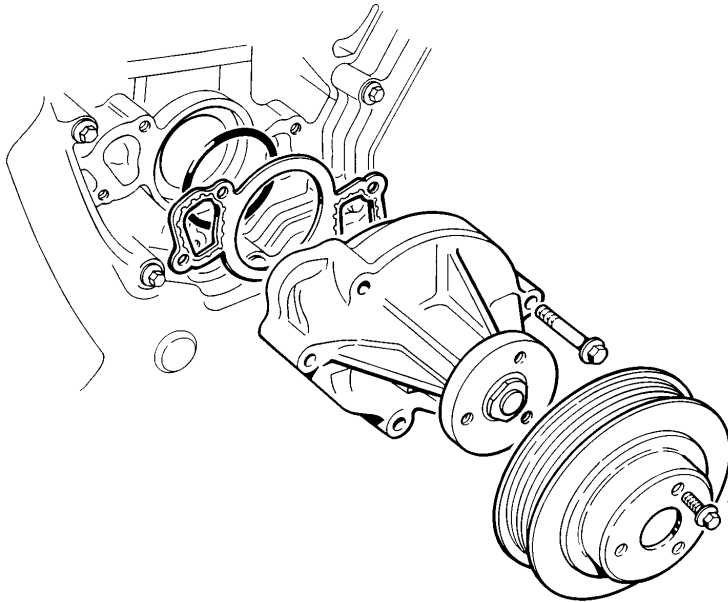
**Note:** Coolant is drained from the right bank of the cylinder block by removing the coolant pipe behind the starter motor.

**COOLING SYSTEM DIAGRAM**



- |                        |                                 |                      |
|------------------------|---------------------------------|----------------------|
| 1. Electronic Throttle | 4. Coolant Pump                 | 7. A/C Heater Supply |
| 2. EGR Valve           | 5. Thermostat Housing           | 8. Bleed Outlet      |
| 3. A/C Heater Return   | 6. Vehicle Radiator (Reference) |                      |

303-028

**COOLANT PUMP**


303-030

**Coolant Pump**

The coolant pump is installed between the two cylinder banks, on the front face of the cylinder block. The pumping element is a shrouded composite impeller. Coolant escapes from seal breather holes in the housing if the pump's bearing seal fails.

An O-ring and an edge bonded rubber/aluminum alloy gasket seal the pump to cylinder block interface. The O-ring seals the inlet port from the thermostat. The gasket seals the outlet ports into the cylinder banks.

**Thermostat Housing**

The composite thermostat housing is installed between the two cylinder banks, immediately above the coolant pump. The thermostat controls the flow of coolant through the radiator. It starts to open at 80 to 84°C (176 to 183°F) and is fully open at 96°C (205°F).

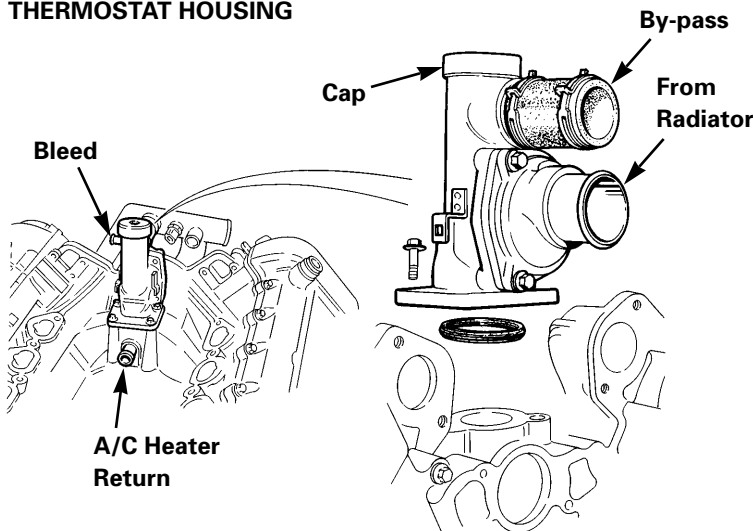
A duct in the cylinder block connects the thermostat housing outlet to the pump inlet. A stub pipe connects the duct to the air conditioning heater matrix return line.

An in-groove gasket seals the joint between the thermostat housing and the cylinder block.

In addition to containing the thermostat, the composite thermostat housing incorporates connections for the bleed, bypass and radiator bottom hoses. The bleed outlet vents any air in the system into the vehicle's coolant reservoir.

The cap of the thermostat housing is removable, to allow air out of the system when filling from empty.

**CAUTION:** Use the correct torque (marked on the cap) when re-installing the cap, or the cap/thermostat housing could be damaged.

**THERMOSTAT HOUSING**


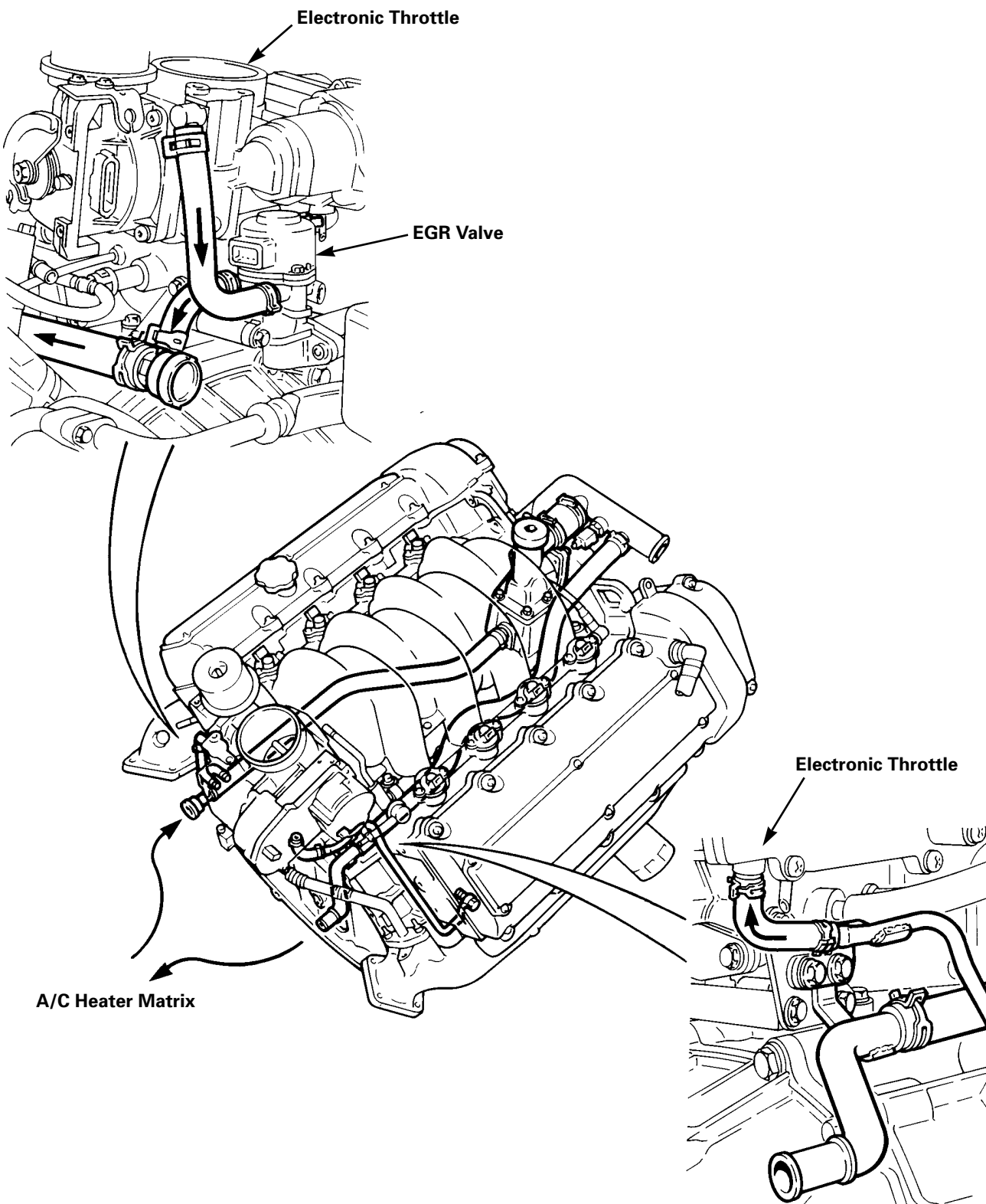
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**Coolant Hoses**

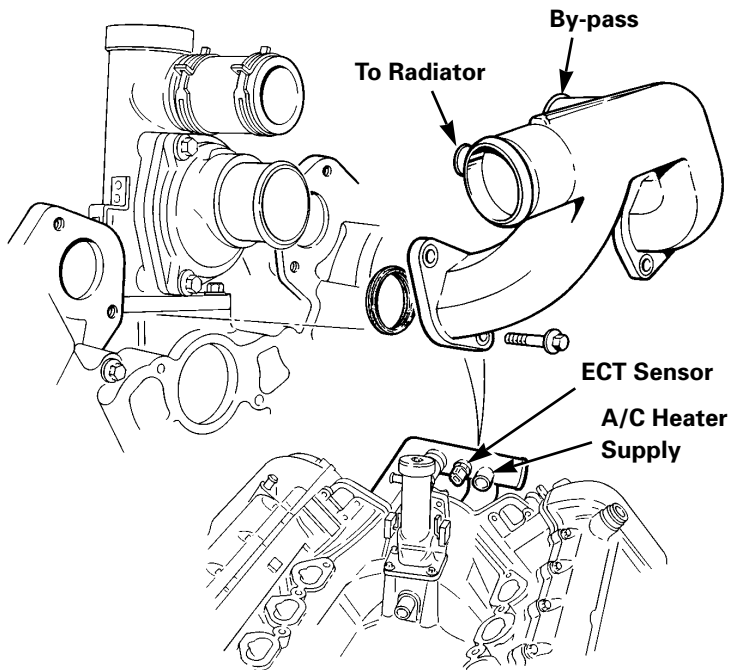
Supply and return hoses for the air conditioning heater matrix are installed between the cylinder banks.

A connection at the rear of A bank provides the coolant supply for the electronic throttle and the EGR valve. The outlet from the EGR valve connects to the return hose of the air conditioning heater matrix.

COOLANT HOSES



303-032

**COOLANT OUTLET DUCT****Coolant Outlet Duct**

The composite coolant outlet duct connects to the outlet port of each cylinder head to provide a common connection point for the radiator top hose. It also incorporates connections for the coolant temperature sensor, the supply to the air conditioning heater matrix, and the bypass flow to the thermostat housing.

An in-groove gasket seals each of the joints between the outlet duct and the cylinder heads.

**Engine Lubrication**

Oil is drawn from the reservoir in the oil pan and pressurised by the oil pump. The output from the oil pump is then filtered and distributed through internal oil passages.

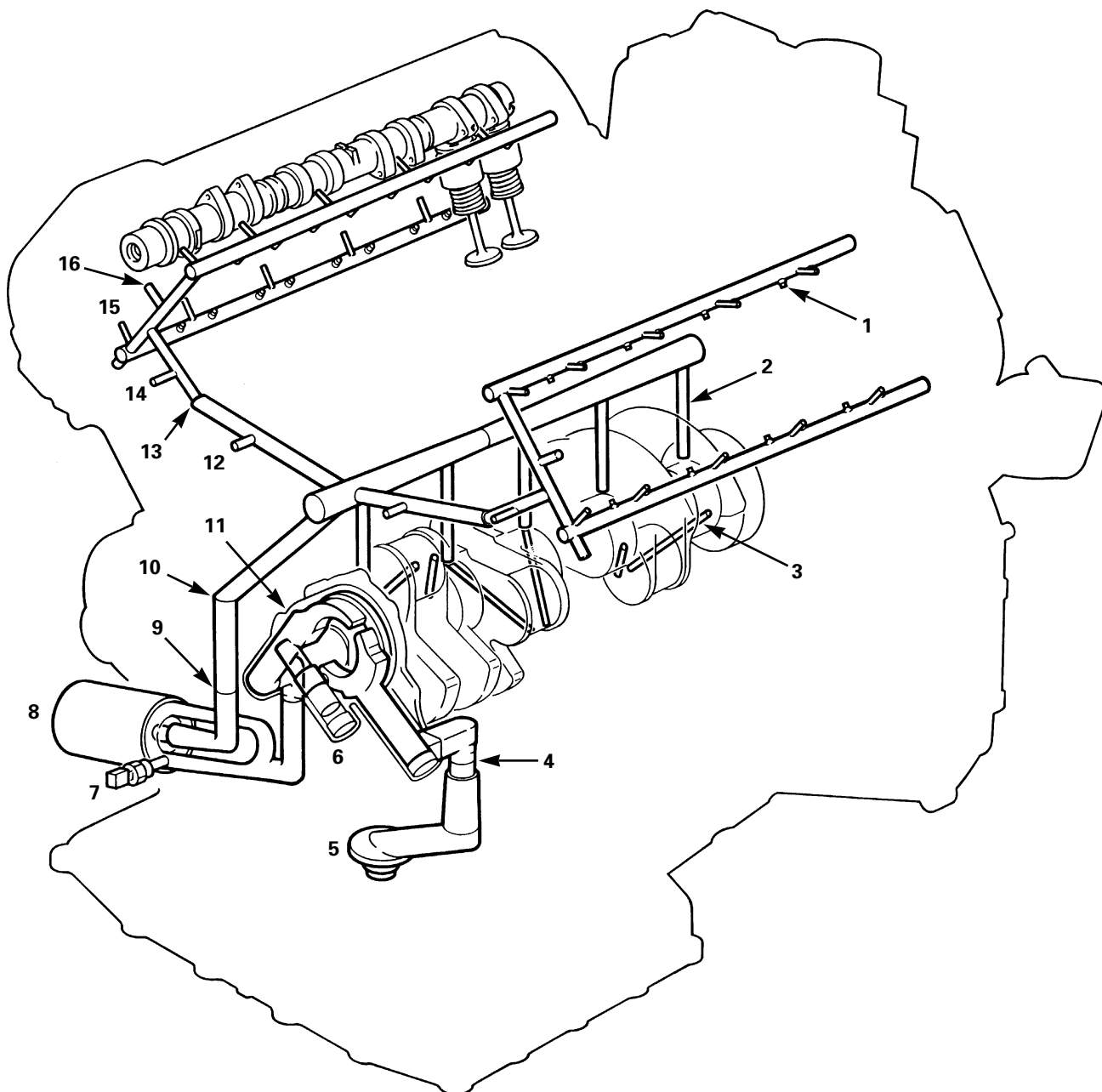
All moving parts are lubricated by pressure or splash oil. Pressurised oil is also provided for operation of the variable valve timing units and the timing gear chain tensioners.

The oil returns to the oil pan under gravity. Large drain holes through the cylinder heads and cylinder block ensure the quick return of the oil, reducing the volume of oil required and enabling an accurate check of the contents soon after the engine stops.

System replenishment is through the oil filler cap on the B bank camshaft cover.

With the exception of the pump and level gauge, all oil system components are installed on the structural sump.

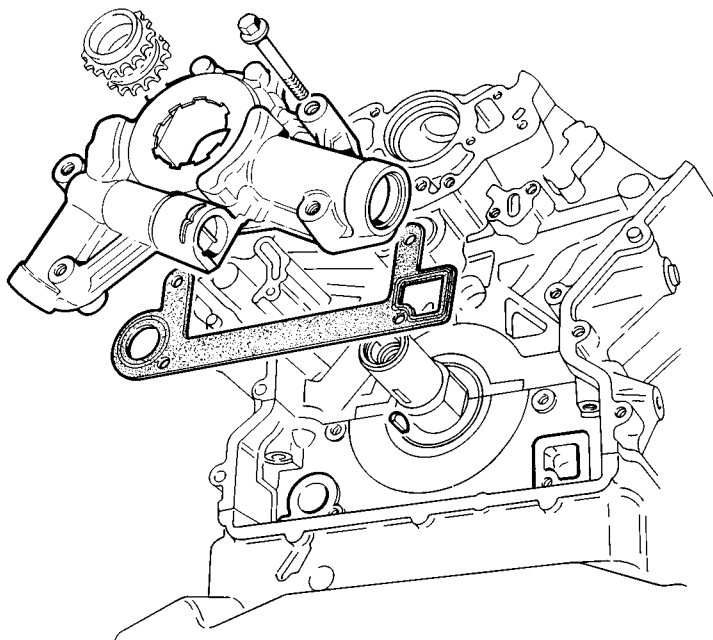
**LUBRICATION SYSTEM**



- |                                      |  |
|--------------------------------------|--|
| 1. Valve Lifter Supply               | 9. Structural Sump/Bedplate Interface      |
| 2. Main Bearing Supply               | 10. Bedplate/Cylinder Block Interface      |
| 3. Connecting Rod Bearing Supply     | 11. Oil Pump                               |
| 4. Bedplate/Cylinder Block Interface | 12. Primary Chain Tensioner Supply         |
| 5. Oil Pick-up                       | 13. Cylinder Block/Cylinder Head Interface |
| 6. Pressure Relief Valve             | 14. Variable Valve Timing Supply           |
| 7. Oil Pressure Switch               | 15. Camshaft Bearing Supply                |
| 8. Oil Filter                        | 16. Secondary Chain Tensioner Supply       |

303-007

## OIL PUMP



303-009

## Oil Pick-up

The moulded composite oil pick-up is immersed in the oil reservoir to provide a supply to the oil pump during all normal vehicle attitudes. The castellated inlet allows the supply to be maintained even if the sump pan is deformed (eg. by "grounding"). A mesh screen in the inlet prevents debris from entering the oil system.

## Oil Pump

The oil pump is installed on the crankshaft at the front of the engine. The pump inlet and outlet ports align with oil passages in the bedplate. A rubber coated metal gasket seals the pump to bedplate interface.

The pumping element is an eccentric rotor, which is directly driven by flats on the crankshaft. An integral pressure relief valve regulates pump outlet pressure at 4.5 bar (65.25 psi).

## Oil Filter

The oil filter is a replaceable cartridge installed on an adapter. An internal bypass facility permits full flow bypass if the filter is blocked.

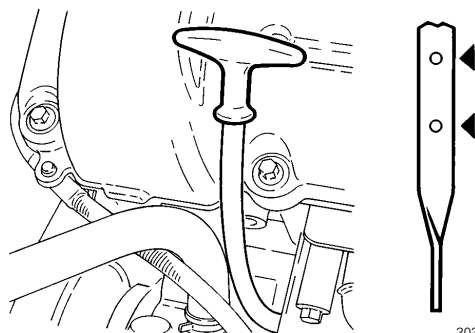
## Oil Pressure Switch

The oil pressure switch connects a ground input to the instrument cluster when oil pressure is present. The switch operates at a pressure of 0.15 to 0.41 bar (2.2 to 5.9 psi).

## Oil Level Gauge

The oil level gauge locates midway along the left side of the oil pan, supported in a tube installed in the bedplate. Two holes in the end of the gauge indicate the minimum and maximum oil levels. There is a difference of approximately 1 liter (1 US quart) between the two levels.

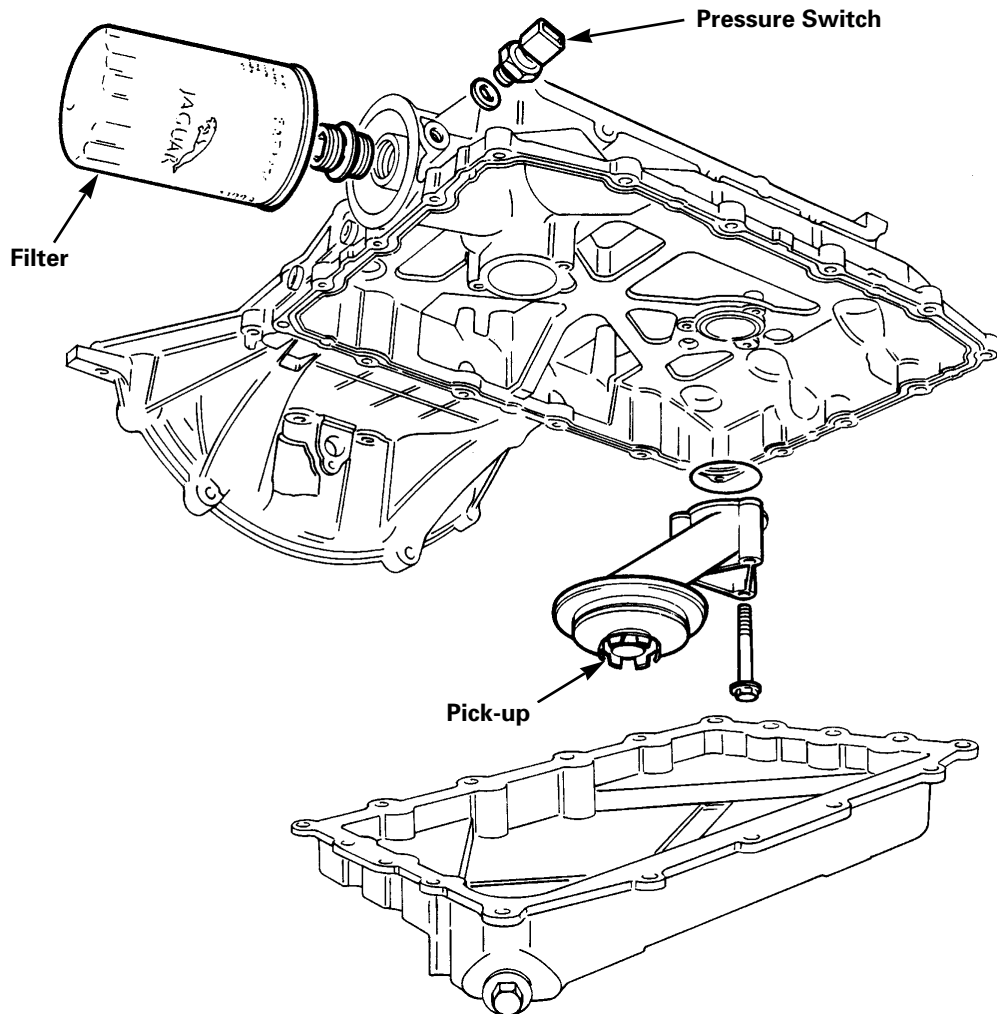
## OIL LEVEL GAUGE



303-022



**OIL SYSTEM COMPONENTS ON STRUCTURAL SUMP**



303-185

## Variable Valve Timing

The variable valve timing system improves low and high speed engine performance, engine idle quality and exhaust emission. It is a two position system that operates on the intake camshafts only. There are 30° of crankshaft movement between the retarded and advanced positions.

Engine oil pressure operates the system under the control of the ECM.

For each intake camshaft there is a valve timing unit, a bush carrier assembly and a valve timing solenoid.

### Valve Timing Unit

The valve timing unit turns the intake camshaft in relation to the primary chain to advance and retard the timing.

The unit consists of a body and sprocket assembly separated from an inner sleeve by a ring piston and two ring gears. A bolt secures the inner sleeve to the camshaft. The ring gears engage in opposing helical splines on the body and sprocket assembly and on the inner sleeve.

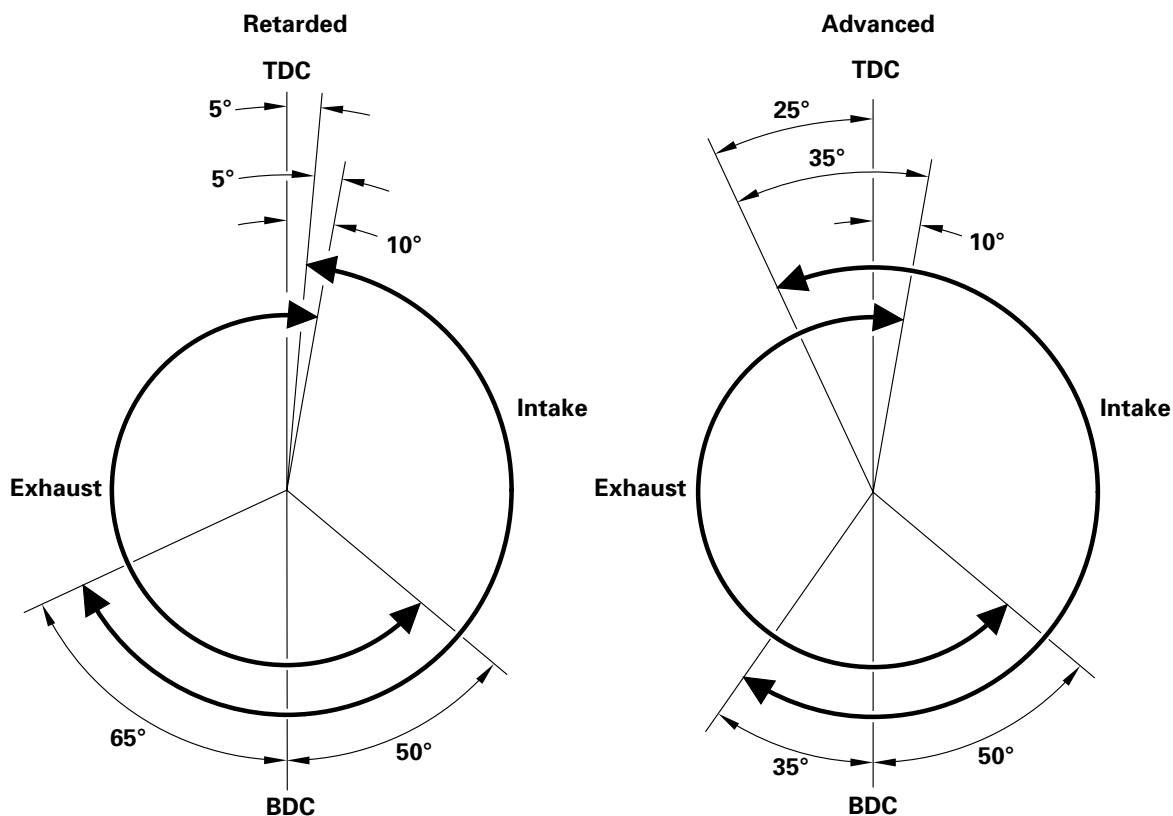
The ring gears transmit the drive from the body

and sprocket assembly to the inner sleeve and, when moved axially, turn the inner sleeve in relation to the body and sprocket assembly.

Engine oil pressure (controlled by the valve timing solenoid) moves the ring gears and piston to turn the inner sleeve in the advanced timing direction. A return spring moves the ring gears and piston to turn the inner sleeve in the retarded timing direction.

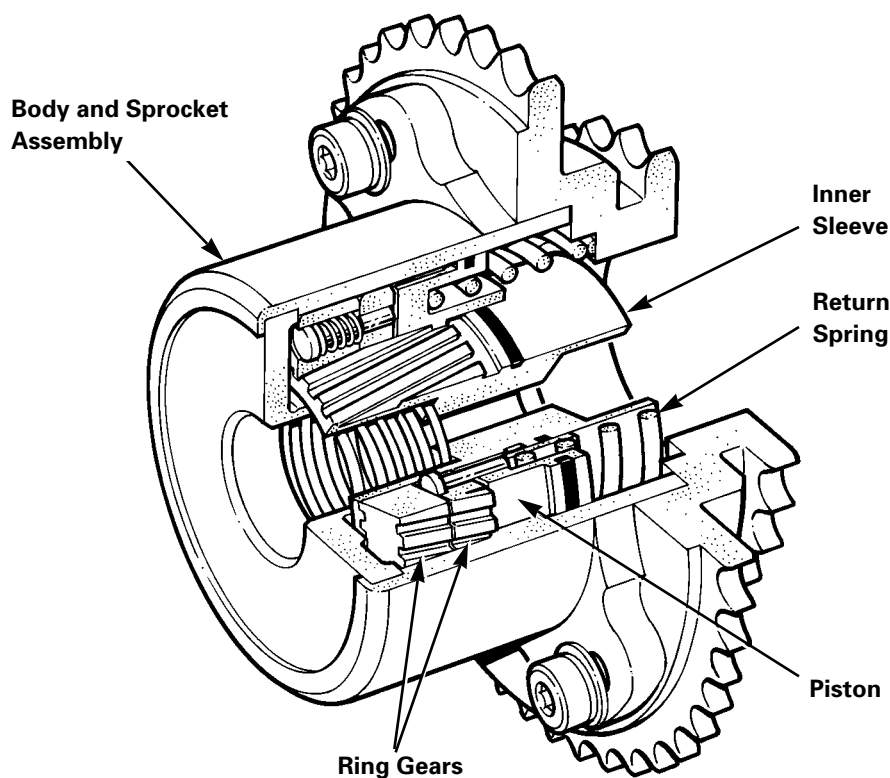
Additional springs absorb backlash to reduce noise and wear. The springs between the ring gears absorb rotational backlash. The spring between the inner sleeve and the end of the body and sprocket assembly absorbs axial backlash.

### VALVE TIMING DIAGRAMS



303-068

### VALVE TIMING UNIT

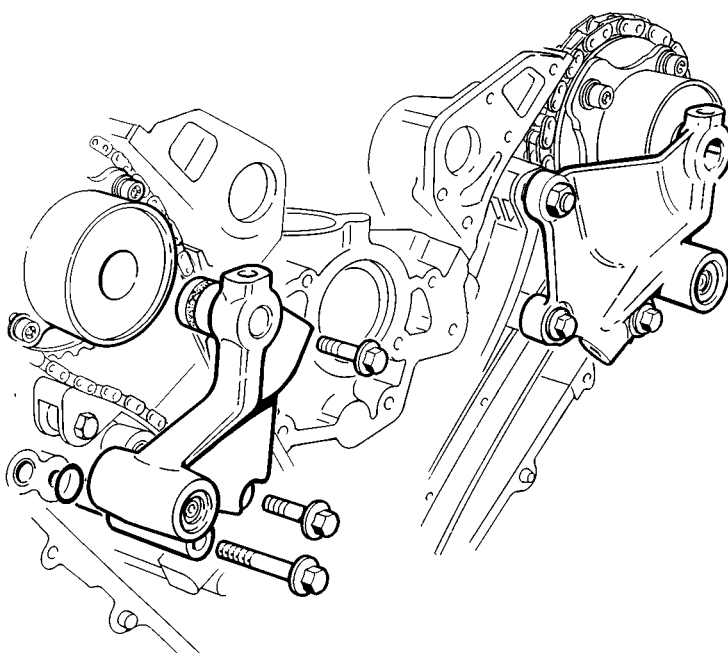


303-002

### Bush Carrier

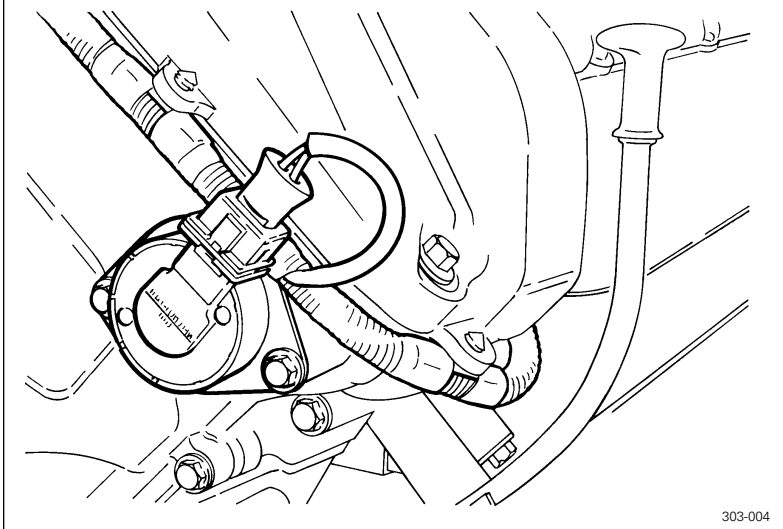
The bush carrier contains oil passages that link the engine oil supply to the valve timing unit. A lug on the bush carrier locates in the central bore of the valve timing unit. Two hollow dowels at the bush carrier to cylinder block interface ensure the lug is accurately located. A scarf-jointed fibre ring seals the joint between the lug and the valve timing unit. An integral shuttle valve, biased by a coil spring, controls the flow of oil through the oil passages.

### BUSH CARRIERS



303-003

## VALVE TIMING SOLENOID



303-004

## Valve Timing Solenoid

The valve timing solenoid controls the position of the shuttle valve in the bush carrier. A plunger on the solenoid extends when the solenoid is energised and retracts when the solenoid is de-energised.

## Operation

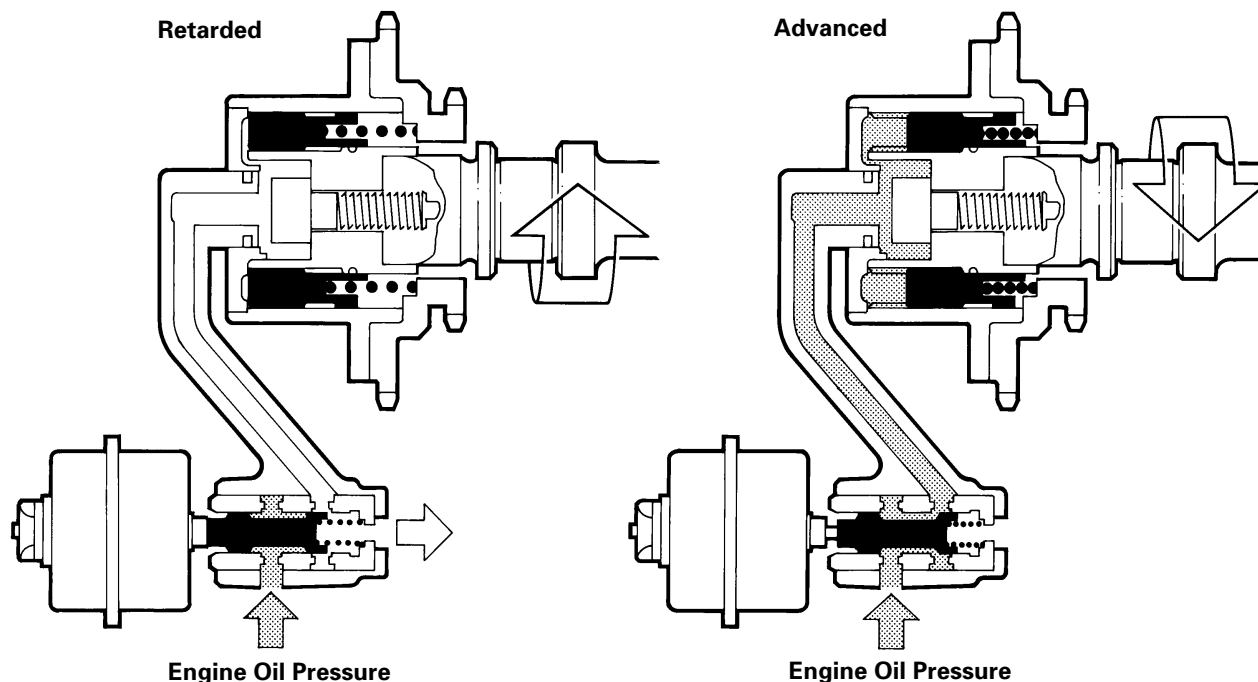
When the valve timing solenoids are de-energised, the coil springs in the bush carriers position the shuttle valves to connect the valve timing units to drain. In the valve timing units, the return springs hold the ring pistons and gears in the retarded position.

When the valve timing solenoids are energised by the ECM, the solenoid plungers position the shuttle valves to direct engine oil to the valve timing units. In the valve timing units, the oil pressure overcomes the force of the return springs and moves the gears and ring pistons to the advanced position.

System response times are 1.0 second maximum for advancing and 0.7 second maximum for retarding.

While the valve timing is in the retarded mode, the ECM produces a periodic lubrication pulse.

## VARIABLE VALVE TIMING OPERATION



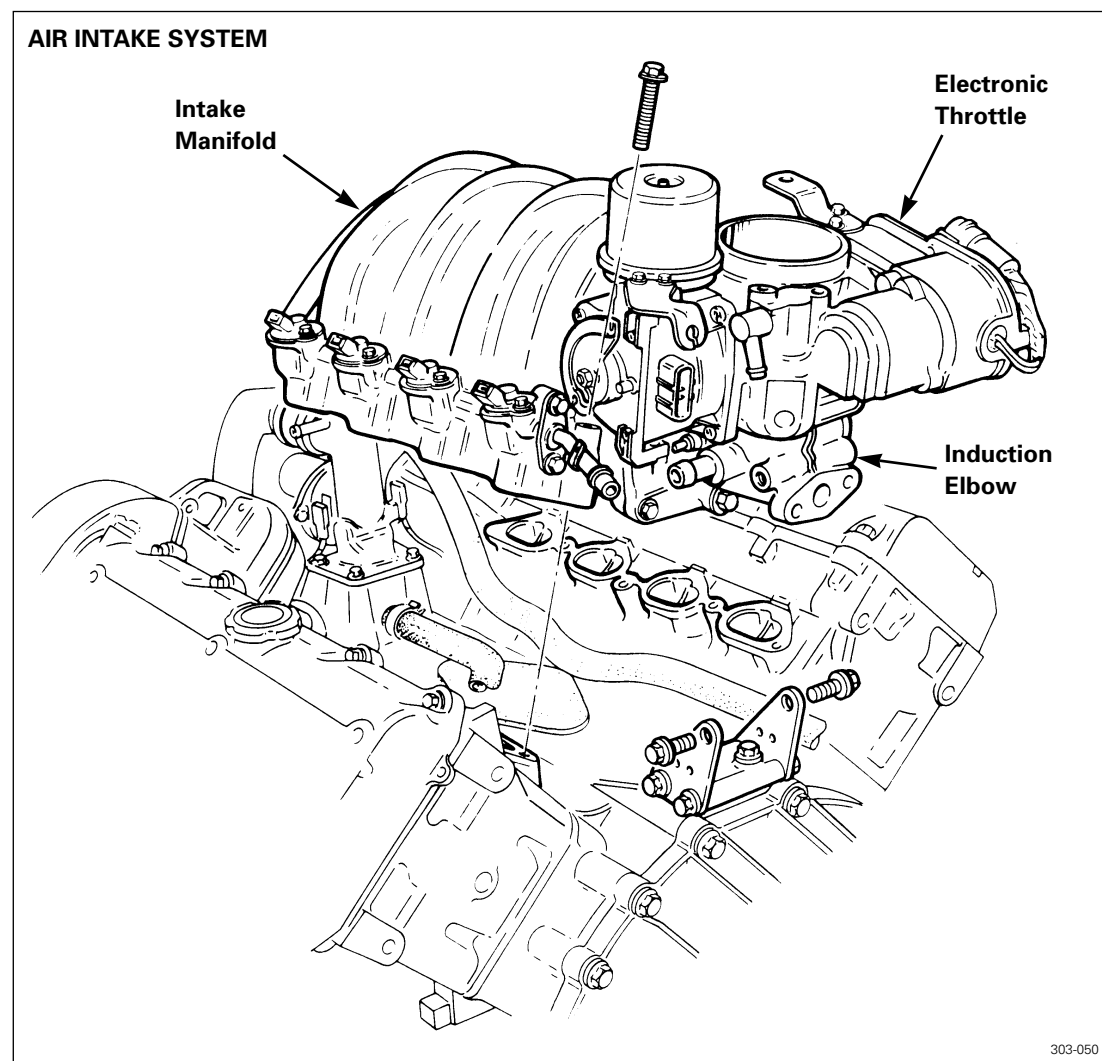
303-005

This momentarily energises the valve timing solenoids to allow a spurt of oil into the valve timing units. The lubrication pulse occurs once every 5 minutes.

**Note:** With the vehicle stationary and the hood open, operation of the valve timing solenoids may be audible when the lubrication pulse occurs at engine idle speed.

## Air Intake System

Filtered air from the vehicle's intake ducting is metered by the electronic throttle then directed through the induction elbow into the intake manifold.



## Electronic Throttle

The electronic throttle enables the ECM to control the flow of air into the engine. It includes:

- an input shaft that receives driver inputs from the accelerator pedal via a conventional throttle cable
- a mechanical guard, to prevent throttle valve position exceeding driver demand and to operate the throttle valve mechanically if the electronic system fails
- a vacuum actuator, to operate the mechanical guard in the cruise control mode of operation
- a throttle valve, to regulate the air flow
- a thermostatic air valve, to control a bypass flow around the throttle valve
- a dc motor, to operate the throttle valve in response to inputs from the ECM
- three position sensors, to supply the ECM with the position's of the input shaft (ie. accelerator pedal), the mechanical guard and the throttle valve
- springs connected to the input shaft, the mechanical guard, the throttle valve and the drive gear of the dc motor.

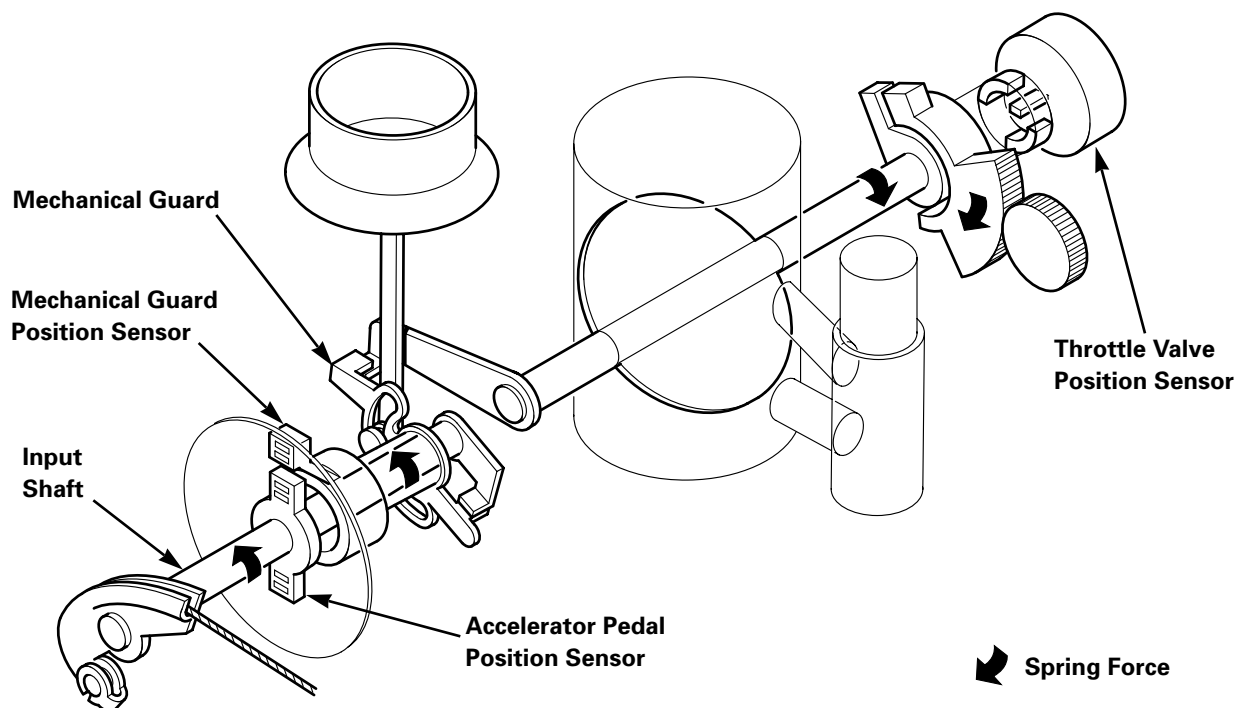
## Vacuum Actuator

On vehicles with cruise control, the vacuum actuator is connected to manifold vacuum and controlled by the ECM. On vehicles without cruise control, the vacuum actuator is open to atmosphere and the actuator is inoperative.

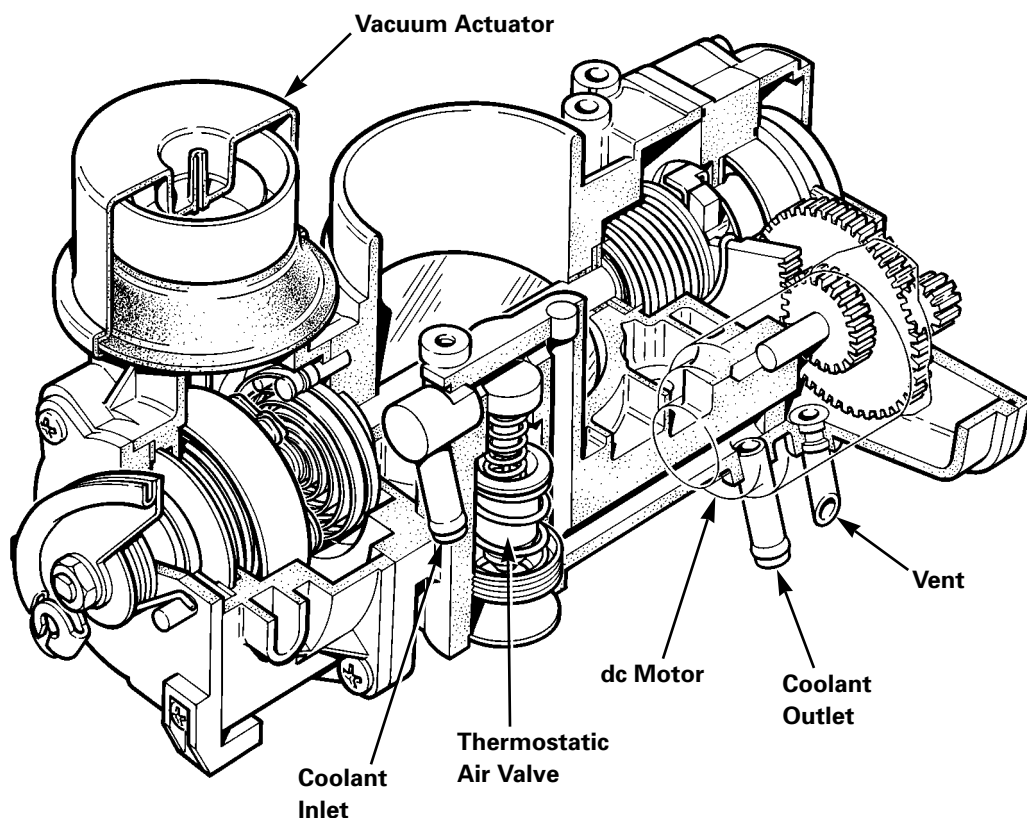
## Thermostatic Air Valve

The thermostatic air valve is a wax capsule operated valve that enables engine starting at low engine temperatures (with the accelerator pedal in the idle position, the degree of throttle valve movement available between fully closed and the mechanical guard is insufficient to start the engine at low temperatures). The thermostatic air valve is fully open at a coolant temperature of approximately  $-30^{\circ}\text{C}$  ( $-22^{\circ}\text{F}$ ) and progressively closes until it is fully closed at  $+40^{\circ}\text{C}$  ( $+104^{\circ}\text{F}$ ). A flow of engine coolant through the throttle body provides the temperature source to operate the thermostatic air valve.

### SIMPLIFIED VIEW OF ELECTRONIC THROTTLE



303-080

**ELECTRONIC THROTTLE**


303-067

**Springs**

The input shaft spring and the mechanical guard spring oppose movement in the throttle open direction, and provide the "feel" of the accelerator pedal. The throttle valve spring and the drive gear spring oppose movement in the throttle closed direction.

**Operation**

The design of the input shaft and the mechanical guard, and the bias of their respective springs, means that, except in cruise control, they always rotate together. The throttle cable turns them in the open direction; the springs keep their adjacent levers locked together and turn them in the closed direction.

The ECM monitors the position of the input shaft and mechanical guard using the inputs from the accelerator pedal and mechanical guard position sensors. During normal operation, when the ECM detects any movement it signals the dc motor to

turn the throttle valve and follow the input shaft and mechanical guard, maintaining a constant gap between the adjacent levers of the throttle valve and mechanical guard. The dc motor drive gears turn the throttle valve in the closed direction; the throttle valve spring turns the throttle valve in the open direction and keeps the throttle valve in contact with the drive gear. Inputs from the throttle valve position sensor enable the ECM to exercise closed loop control. The arrangement of the throttle valve drive prevents the ECM from exceeding driver demand, since if the motor is driven fully open the throttle valve engages the mechanical guard and disengages from the dc motor drive gears. The arrangement of the mechanical guard to throttle valve interface allows the ECM to reduce throttle opening to less than driver demand, eg. during stability/traction control or engine power limiting.

At idle, the ECM controls engine speed using the restricted throttle valve movement available between the mechanical guard (open limit) and a factory set stop on the dc motor drive gear (closed limit).

When cruise control is engaged, the ECM calculates the required throttle valve opening and operates the vacuum system connected to the vacuum actuator. The vacuum actuator then turns the mechanical guard to a position that allows the required throttle valve opening. The inputs from their respective position sensors allow the ECM to monitor and adjust the mechanical guard and the throttle valve to maintain the set speed. As the driver releases the accelerator pedal, the input shaft disengages from the mechanical guard. Note that during cruise control, when

accelerating above the set speed, the accelerator pedal has a lighter "feel" until the input shaft engages with the mechanical guard again.

Mechanical operation of the throttle valve occurs if the ECM selects the mechanical guard mode of operation after detecting a fault. The ECM de-energizes the dc motor and the throttle valve spring turns the throttle valve in the open direction until it engages the mechanical guard. The input shaft, mechanical guard and throttle valve are then effectively locked together by their springs, so that the throttle cable is in direct control of the throttle valve. When the throttle valve opens, it turns the dc motor drive gears. On subsequent closing of the throttle valve the drive gears remain in the open position, disengaged from the throttle valve.

### **Operating Modes (Refer to the figure, page 31)**

#### **Normal**

1. Throttle cable inputs driver demand
2. Input shaft turns mechanical guard
3. Sensors supply ECM with inputs of driver demand
4. ECM operates dc motor
5. Sensor supplies ECM with inputs of throttle valve position
6. Gap maintained between throttle valve and mechanical guard

#### **Cruise Control**

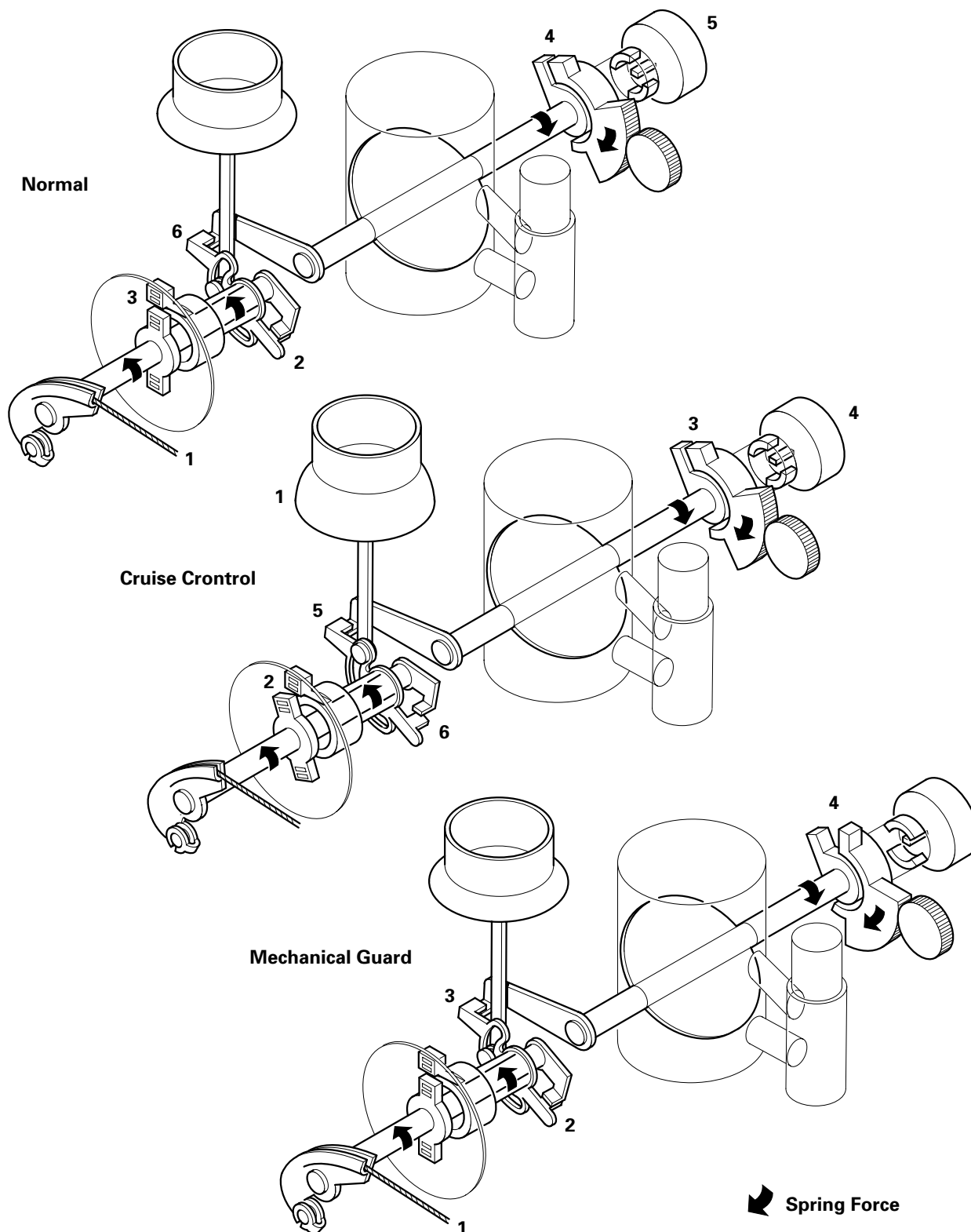
1. Vacuum actuator turns mechanical guard
2. Sensor supplies ECM with mechanical guard position
3. ECM operates dc motor
4. Sensor supplies ECM with inputs of throttle valve position
5. Gap maintained between throttle valve and mechanical guard
6. Input shaft at idle position, disengaged from mechanical guard

#### **Mechanical Guard**

1. Throttle cable inputs driver demand
2. Input shaft turns mechanical guard
3. Mechanical guard turns throttle valve
4. dc motor drive disengaged from throttle valve

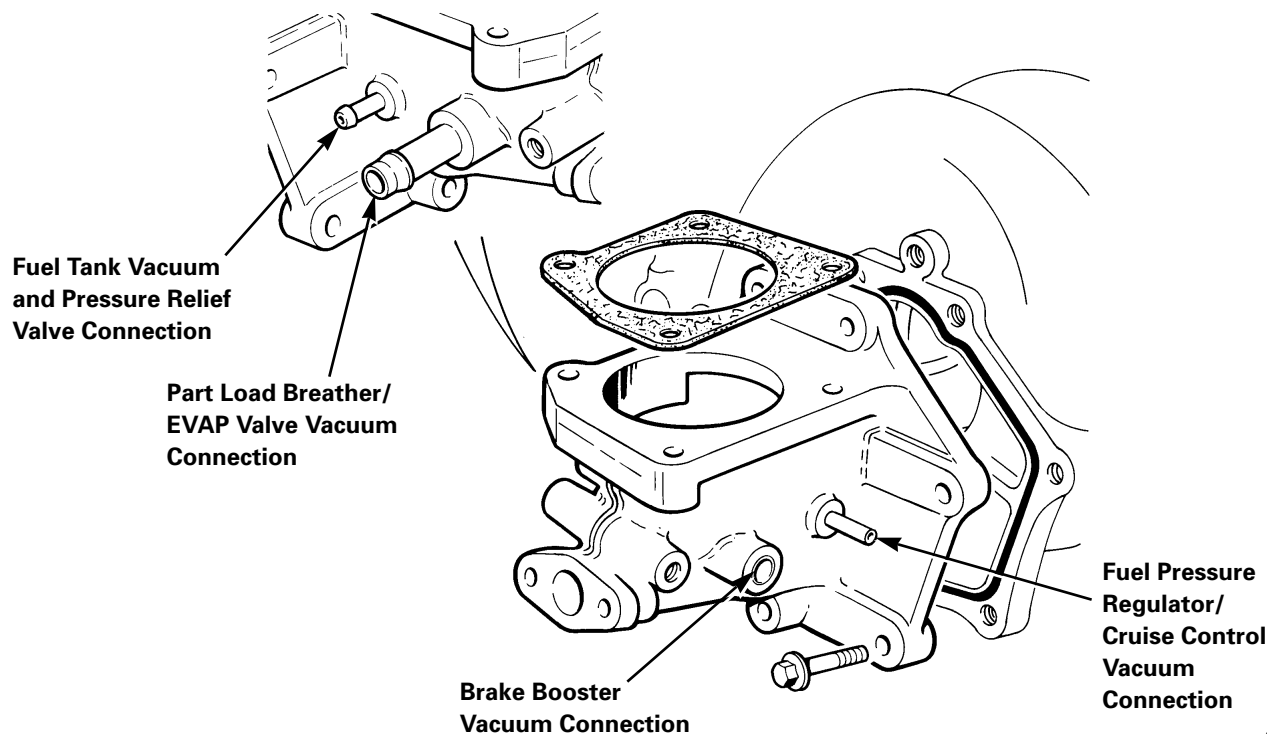


**ELECTRONIC THROTTLE OPERATING MODES**



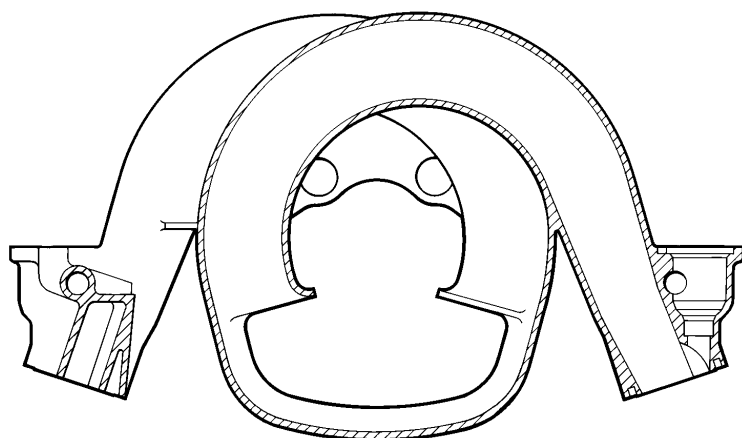
303-080,081/082

**INDUCTION ELBOW**



303-033

**SECTION THROUGH INTAKE MANIFOLD**



303-051

**Induction Elbow**

The induction elbow provides the interface between the electronic throttle and the intake manifold. Connections on the induction elbow provide vacuum take-offs for various services. A boss on the rear of the elbow accommodates the EGR valve.

**Intake Manifold**

The intake manifold is manufactured in composite, with integrated composite fuel rails and metal thread inserts. Individual ducts lead off a central chamber to the inlet ports of each cylinder.

Silicon rubber gaskets, located in channels in the intake manifold, seal the joints between the ducts and the cylinder heads.

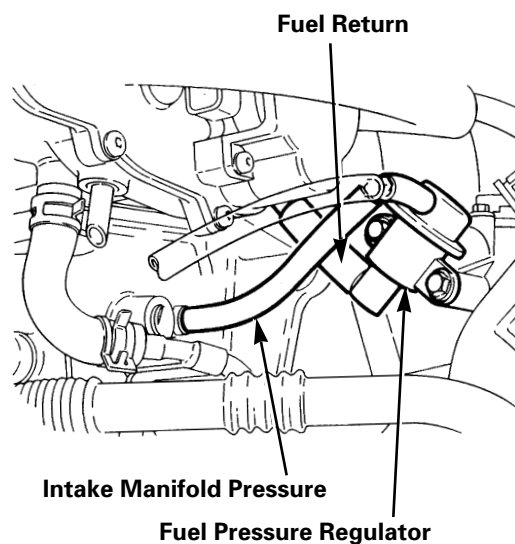
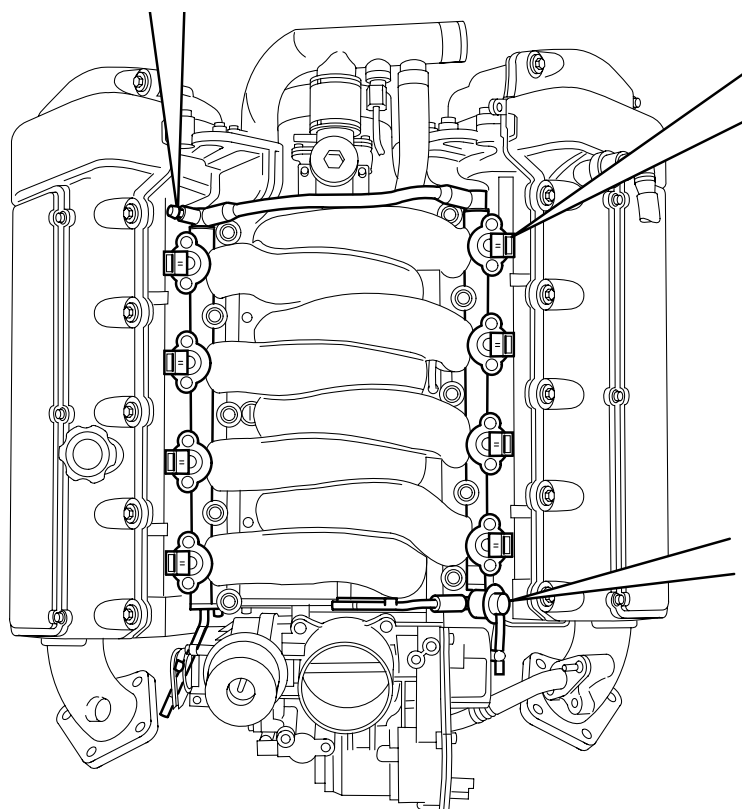
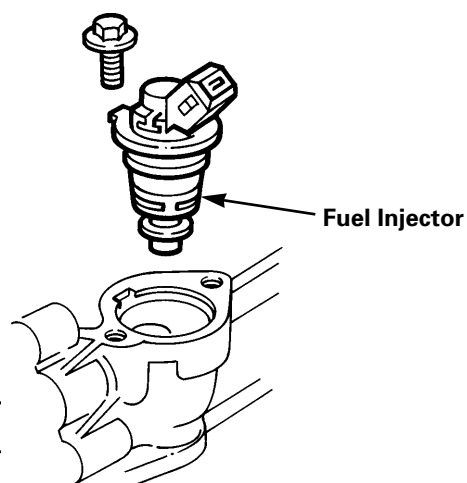
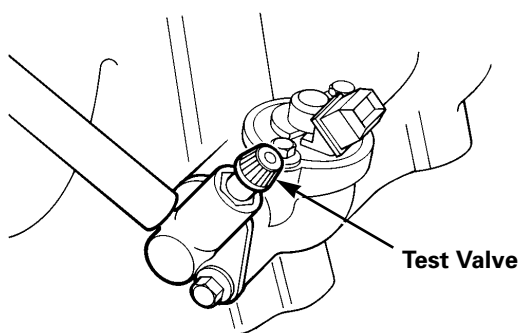
## Fuel System

Fuel injectors, controlled by the ECM, are installed in the fuel rails on each side of the intake manifold. A cross-over pipe connects the two fuel rails together at the front of the manifold. A test valve in the cross-over pipe allows the fuel rail to be pressurised and depressurised during servicing and troubleshooting.

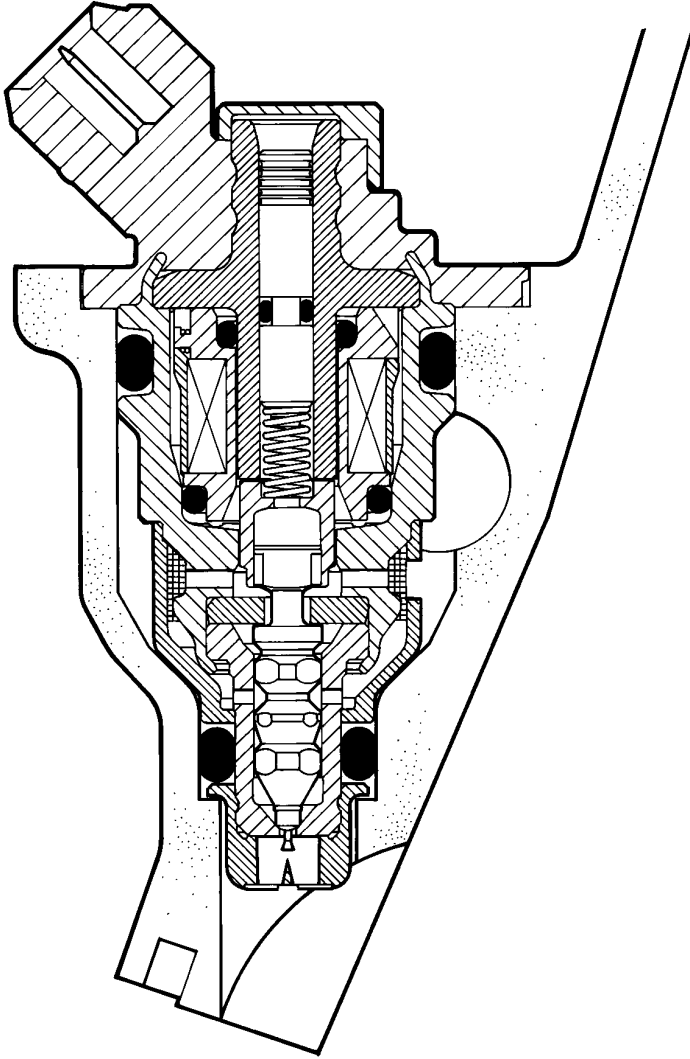
A pressure regulator on the rear of the right fuel rail controls the pressure in the fuel rails.

A return line directs excess fuel from the pressure regulator back to the fuel tank.

### FUEL SYSTEM



303-024/059/078/155

**FUEL INJECTOR**

303-025

**Fuel Injectors**

Eight, side fed, dual straight jet, fuel injectors are installed in the fuel rails. The injectors are electromagnetic solenoid valves controlled by the ECM. Two O-rings seal each injector to manifold interface. The fuel jets from the injectors are directed onto the back of the intake valves.

**Pressure Regulator**

The pressure regulator is a diaphragm operated valve that regulates fuel rail pressure at 2.9 bar (42.05 psi) above intake manifold pressure.

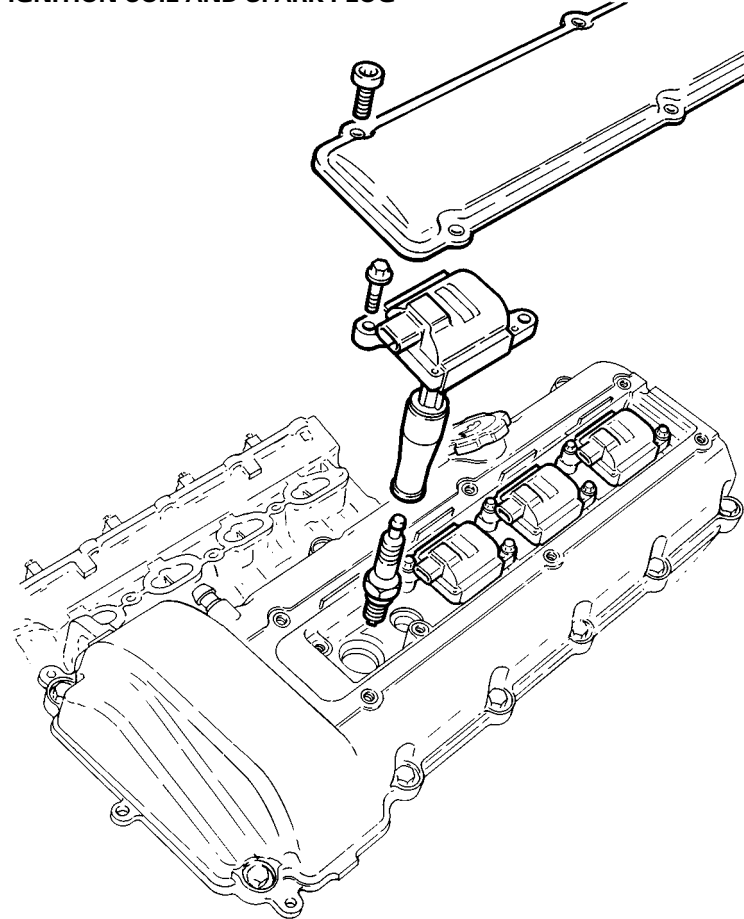
## Ignition System

The ignition system consists of two ECM controlled ignition amplifier modules, which each supply four spark plug mounted ignition coils.

The 14 mm spark plugs, one per cylinder, locate in recesses down the center-line of each cylinder head.

The on-plug ignition coils are secured to the camshaft covers. The engine harness connects the on-plug ignition coils to the ignition amplifiers located on the vehicle body. A composite cover fits over the on-plug coils.

**IGNITION COIL AND SPARK PLUG**



303-049

## Crankcase Ventilation

The engine is ventilated through a part load and a full load breather.

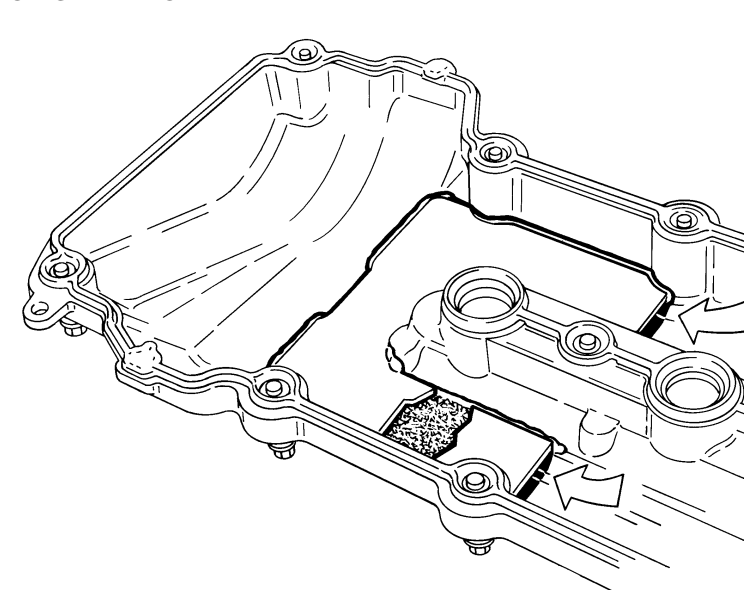
The part load breather is a flexible composite hose connected between the oil separator in B bank camshaft cover and the induction elbow. A restrictor in the outlet from the oil separator prevents reverse flow.

The full load breather is a flexible composite hose connected between the oil separator in A bank camshaft cover and the air intake duct.

The ends of the breather hoses incorporate quick release connectors (see figure, page 36).

The oil separators consist of wire gauze packed into an open ended enclosure below the breather outlet.

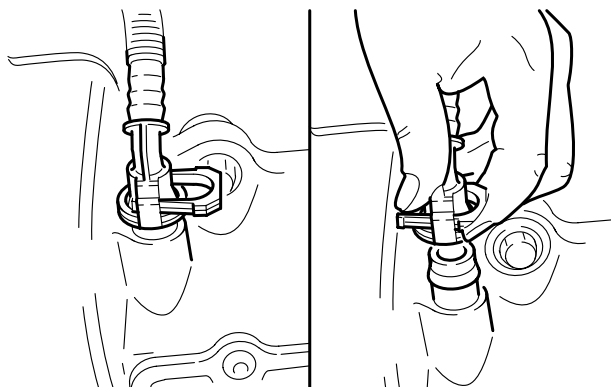
**OIL SEPARATOR**



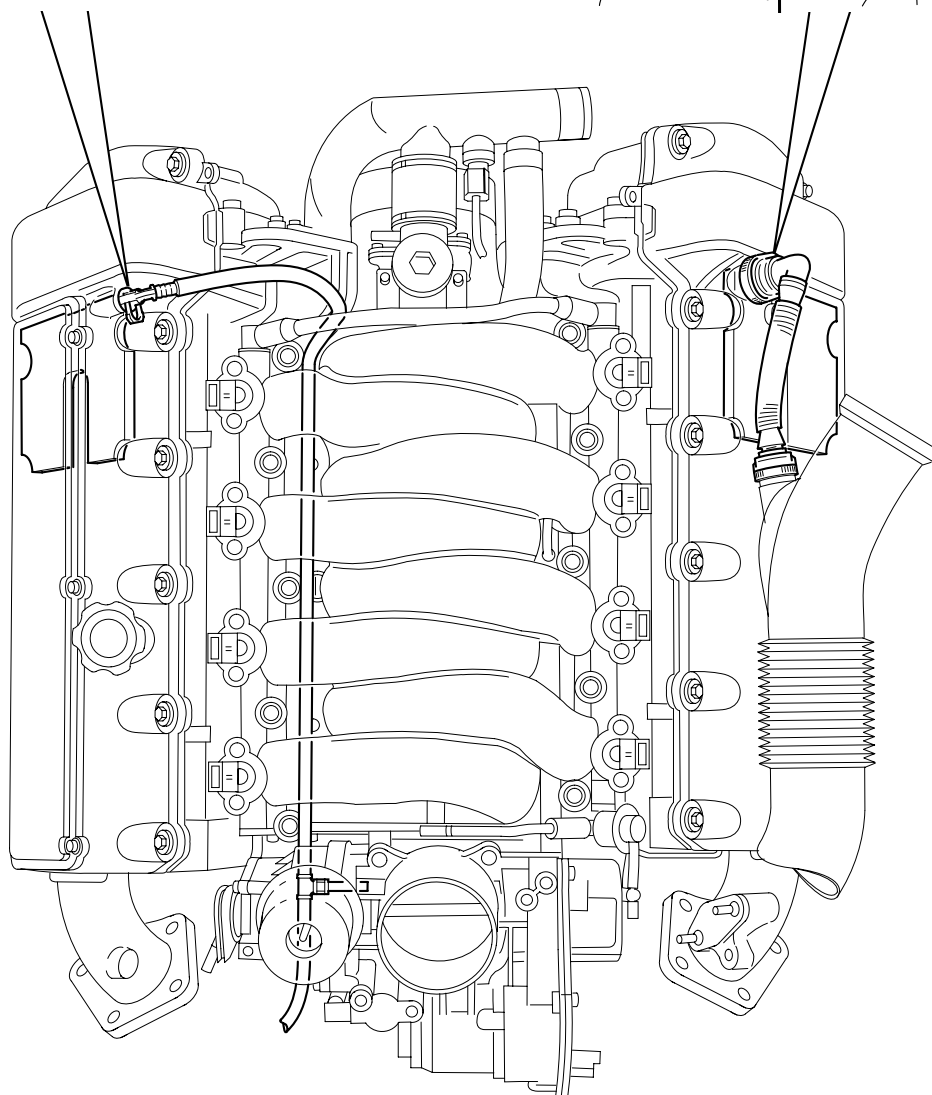
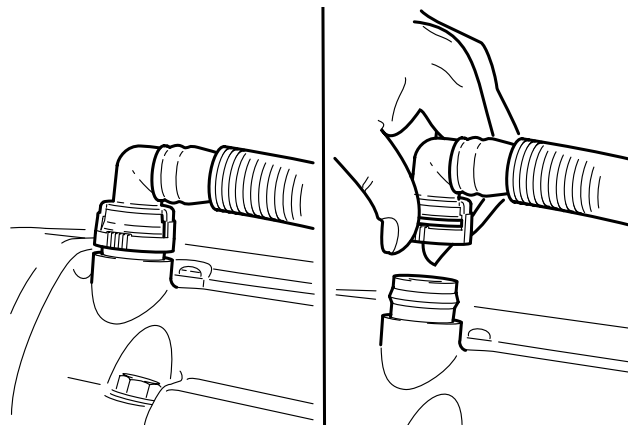
303-046

**CRANKCASE VENTILATION SYSTEM**

**Part Load Breather Hose Connector**



**Full Load Breather Hose Connector**



303-065/077/079

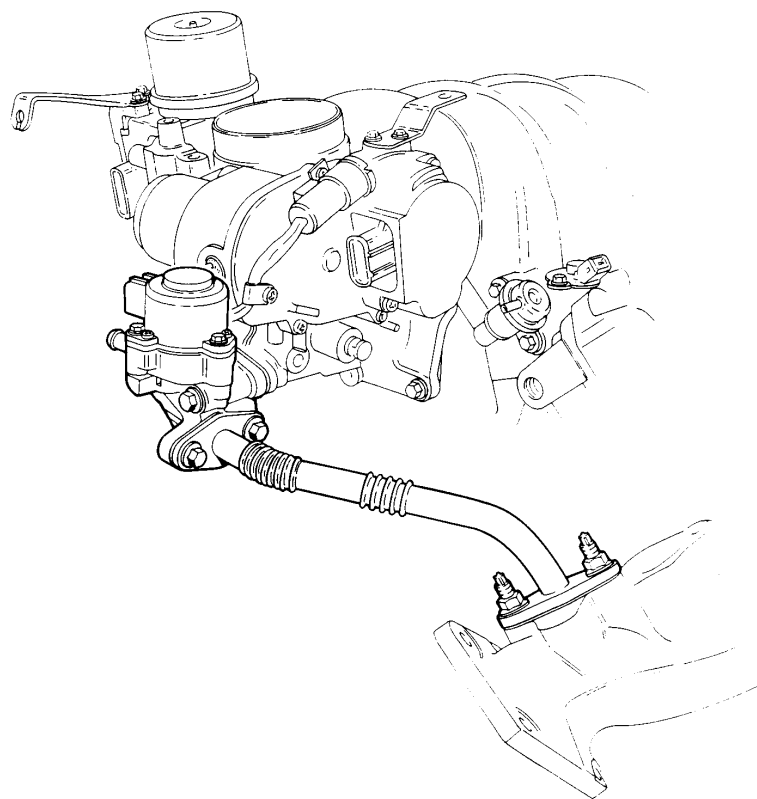
## EGR System

The EGR system is controlled by the ECM and consists of an EGR valve and a transfer pipe.

The EGR valve is a 4 pole stepper motor installed on the rear of the induction elbow. The valve is cooled by the coolant return from the electronic throttle.

The transfer pipe connects the right exhaust manifold to the EGR valve.

**EGR VALVE AND TRANSFER PIPE**



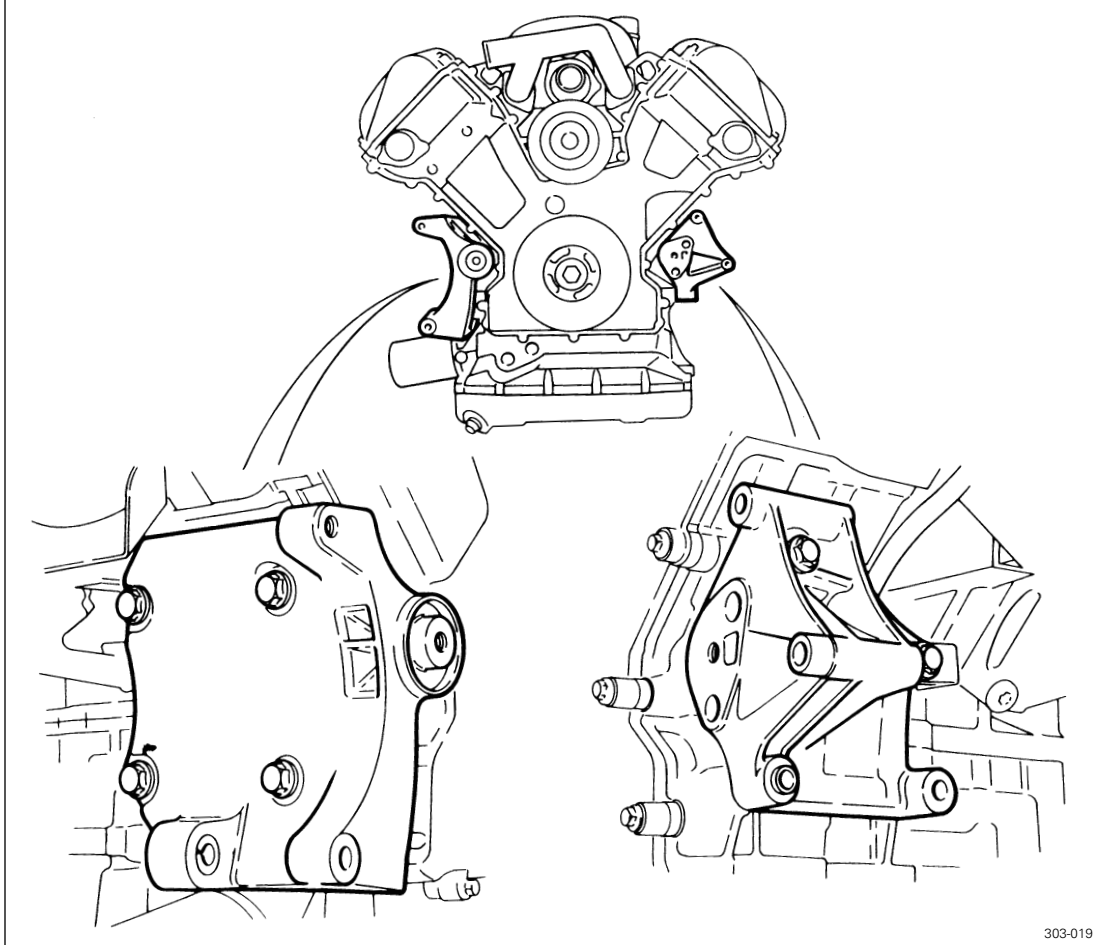
303-048

## Engine Accessories

All engine accessories are rigidly mounted to improve refinement, ie. there are no shock mounts.

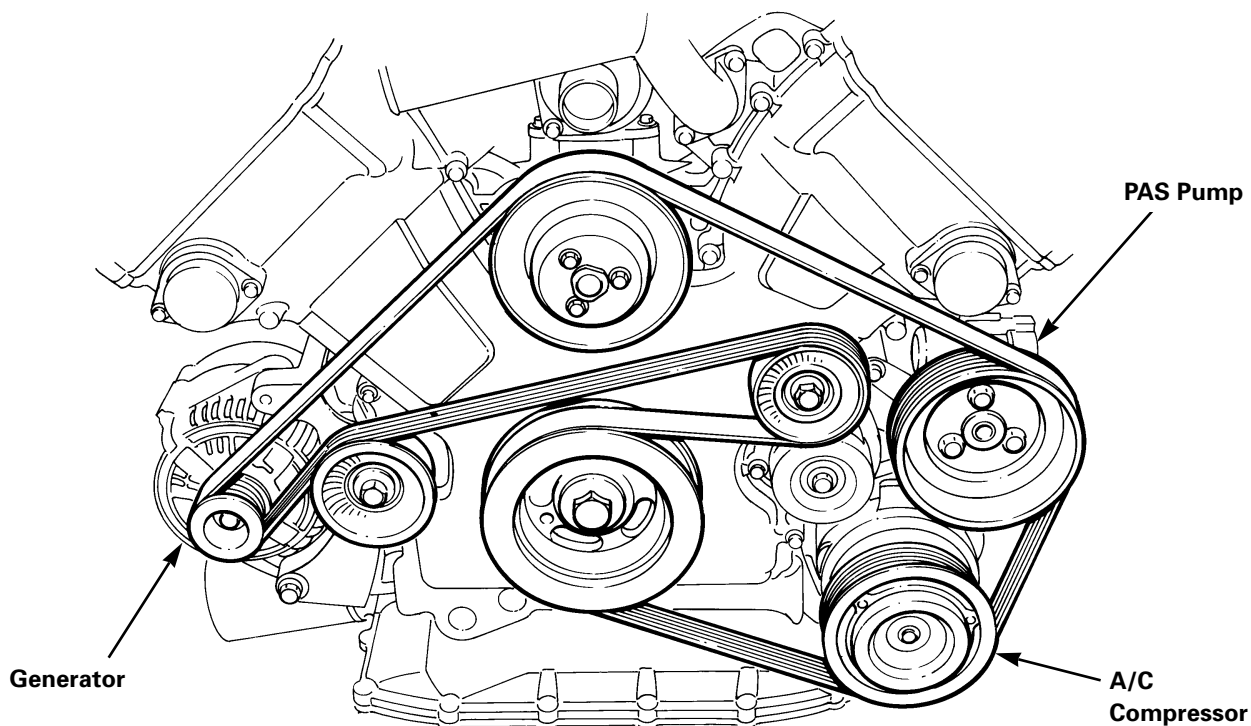
Accessory mounting brackets on the left and right sides of the engine support the A/C compressor/ PAS pump and the generator respectively. Dowels between the accessory mounting brackets and the engine ensure the accessory pulleys are accurately aligned with the accessory drive belt (for further details of the accessories see Technical Guide, XK8 Introduction).

### ACCESSORY MOUNTING BRACKETS





## ENGINE ACCESSORIES AND DRIVE BELT



303-018

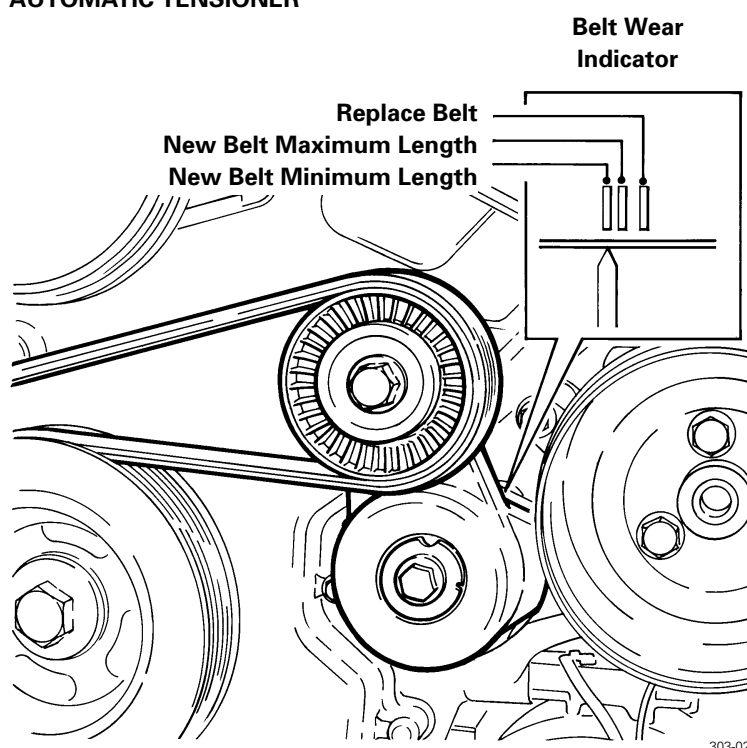
## Accessory Drive

A single seven ribbed belt drives all the engine mounted accessories. The torsional vibration damper on the front of the crankshaft drives the belt. An automatic tensioner, located on the left accessory mounting bracket, keeps the belt at the correct tension. An idler pulley on the right accessory mounting bracket increases the wrap angle around the generator pulley.

The torsional vibration damper incorporates compressed rubber between its inner and outer diameters to absorb vibration and shock loads.

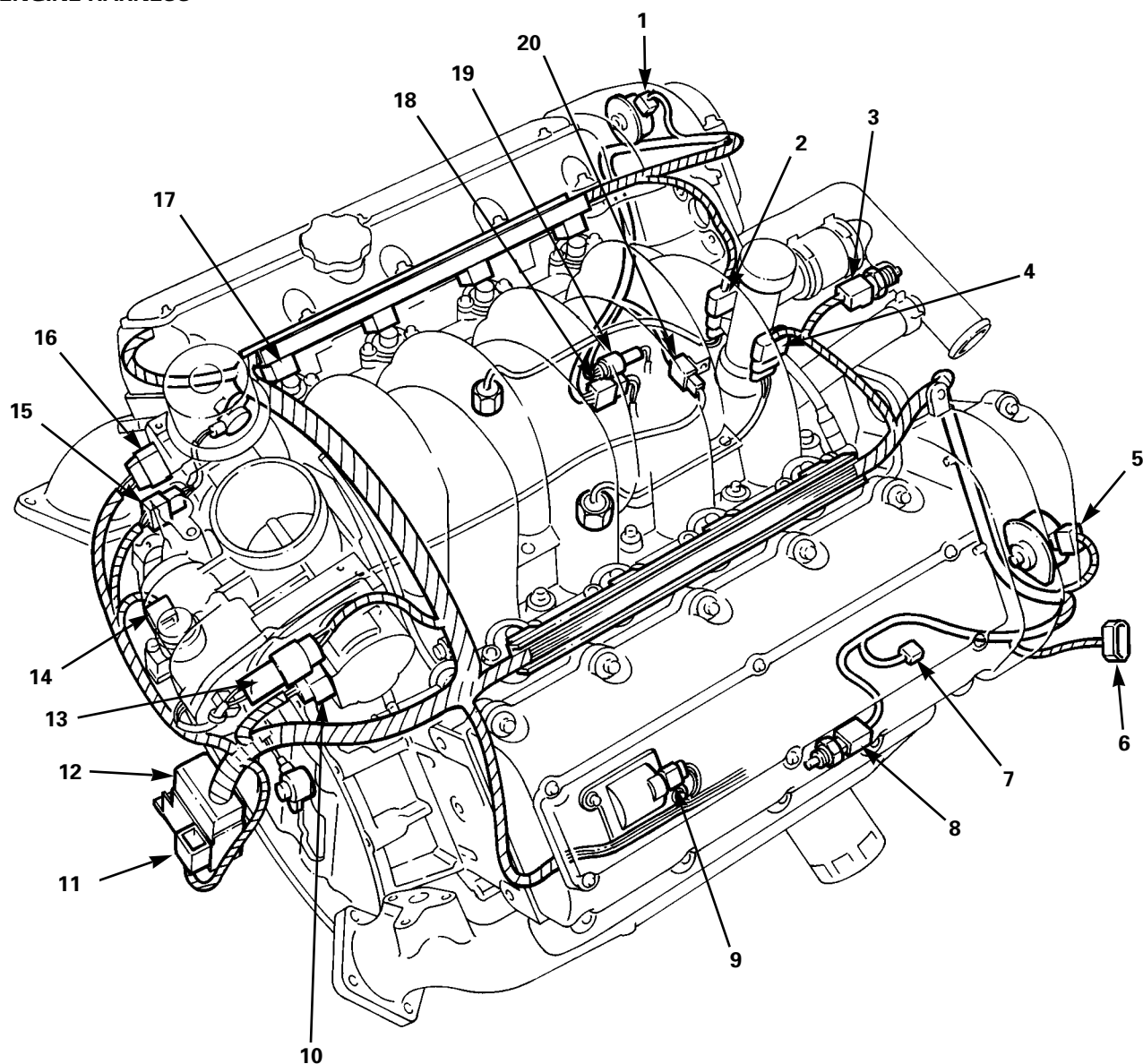
The automatic tensioner consists of an idler pulley on the end of a spring loaded pivot arm. The pivot arm can be turned counter-clockwise (viewed from the front of the engine) for removal and installation of the belt. A belt wear indicator is incorporated on the rear of the pivot arm.

## AUTOMATIC TENSIONER



303-020

## ENGINE HARNESS



### Connectors

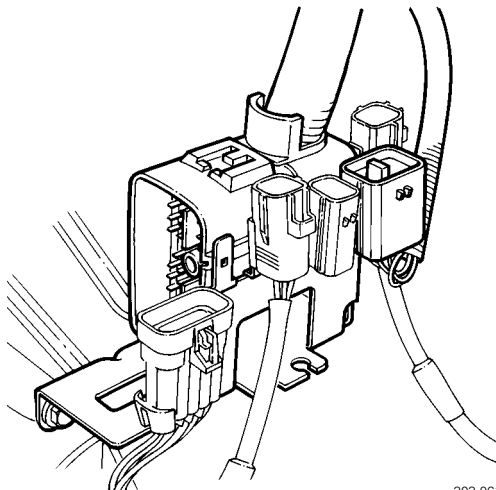
- |   |  |
|---|--|
| 1. PI032, B Bank VVT solenoid   | 11. PI002, Engine Management Harness (On vehicle)                          |
| 2. PI027, B Bank Knock Sensor   | 12. PI001, Engine Management Harness (On vehicle)                          |
| 3. PI004, Engine Coolant Temperature Sensor   | 13. PI033, Throttle Valve Motor  |
| 4. PI026, A Bank Knock Sensor   | 14. PI034, EGR Valve   |
| 5. PI031, A Bank Valve Timing Solenoid  | 15. PI015, Camshaft Position Sensor  |
| 6. PI035, MAFS (On vehicle)   | 16. PI042, Accelerator Pedal and Mechanical Guard Position Sensors         |
| 7. PI050, Generator   | 17. PI007-PI010, A Bank Injectors 1-4<br>PI011-PI014, B Bank Injectors 1-4 |
| 8. PI040, Oil Pressure Switch   | 18. PI037, A/C Compressor Lock Sensor                                      |
| 9. PI018-PI021, A Bank Ignition Coils 1-4<br>PI022-PI025, B Bank Ignition Coils 1-4 | 19. PI036, A/C Compressor Clutch   |
| 10. PI006, Throttle Position Sensor   | 20. PI017, Engine Speed Sensor   |

303-057

## Engine Harness

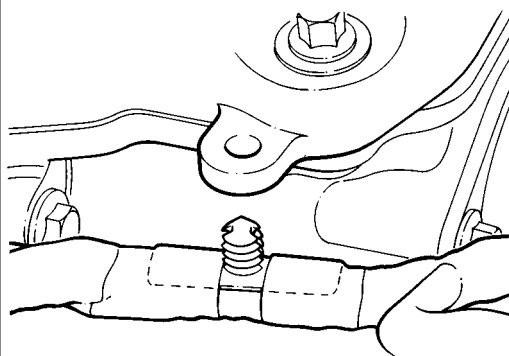
The engine harness links engine mounted electrical components to the vehicle's engine management harness. The connectors that interface with the engine management harness are attached to a bracket on the transmission housing. Integral nylon fasteners attach the harness to the engine. Connectors on component flying leads are attached to engine mounted brackets.

**CONNECTORS ON TRANSMISSION HOUSING BRACKET**



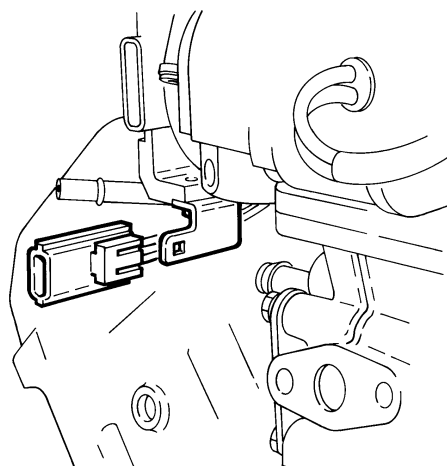
303-061

**HARNESS FASTENER**



303-064

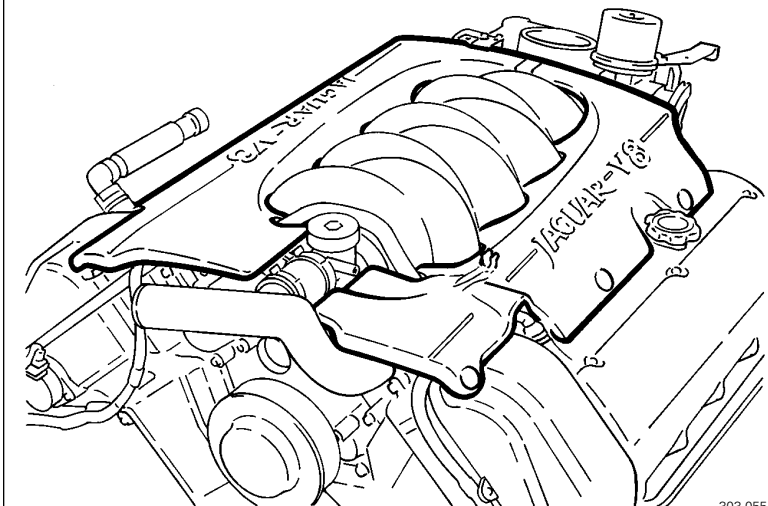
**FLYING LEAD CONNECTOR BRACKET**



303-058

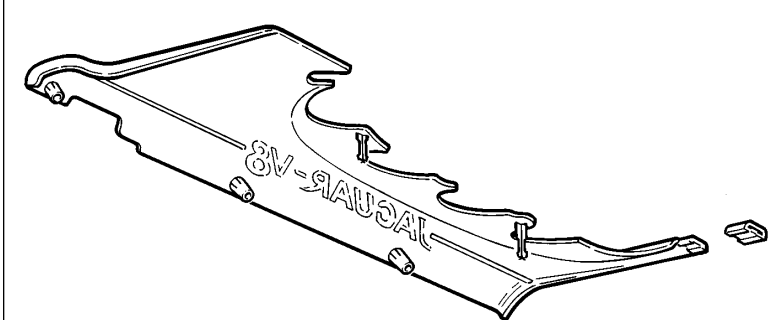
## Engine Covers

### ENGINE COVERS

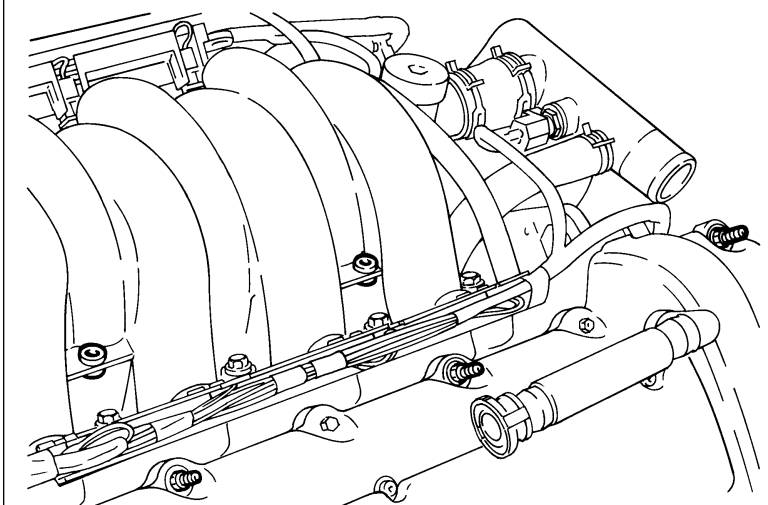


Engine covers are installed over the fuel injectors. The covers are a push fit, held in position by mating studs and grommets on the covers and the engine. The rubber grommets isolate the covers from the engine to prevent noise. A sleeve connects the covers together at the rear.

### MOUNTING POINTS ON ENGINE COVER



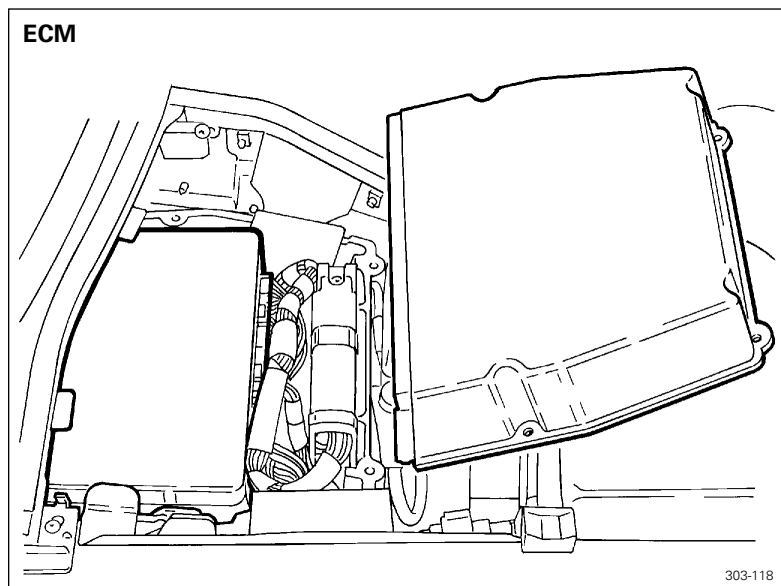
### MOUNTING POINTS ON ENGINE



## Engine Specifications

Configuration	90° V8
Cylinder Head	Dual overhead camshafts, 4 valves per cylinder
Valve Clearances (Cold):	
Intake	0.18 to 0.22 mm (0.007 to 0.009 in)
Exhaust	0.23 to 0.27 mm (0.009 to 0.011 in)
Spark Plug Type:	NGK PFR5011E (platinum tipped center electrode)
Spark Plug Gap:	1.0 mm (0.040 in)
Firing Order	1A, 1B, 4A, 2A, 2B, 3A, 3B, 4B
Bore	86 mm (3.386 in)
Stroke	86 mm (3.386 in)
Displacement	3.996 liters (244 CDl)
Compression Ratio	10.75 : 1
Maximum Power (DIN)	216 kW (290 BHP) at 6100 rpm
Maximum Torque (DIN)	393 Nm (290 lbf. ft) at 4250 rpm
Maximum Speed (Limited)	7100 rpm
Coolant Type	Water and Jaguar anti-freeze to specification ESD-M97B49-A (see Service Manual for mixture ratio)
Coolant Volume:	
Engine Only	3.7 liters (0.98 US gallon)
Complete System	10 liters (2.65 US gallons)
Oil Specification:	SAE 5W30 - API SH/ILSAC GF-2
Oil Volume:	6.5 liters (6.88 US quarts)
Weight (With Accessories)	Approximately 200 kg (441 lb)

## ECM



The engine management system is controlled by the ECM, which is installed in the control module enclosure in the engine compartment. The ECM provides optimum control of the engine under all operating conditions. It also incorporates a comprehensive monitoring and diagnostic capability. Software variations ensure that the system complies with the latest diagnostic and emissions legislation of the destination market. The ECM receives inputs from engine related sensors and various vehicle systems, and provides outputs for the following:

- electronic throttle
- fuel pump
- fuel injection
- ignition
- EVAP system
- variable valve timing
- EGR system
- engine starting
- HO2S heaters
- instrument cluster
- A/C compressor clutch
- windshield and backlight heaters
- radiator cooling fans
- diagnostics.

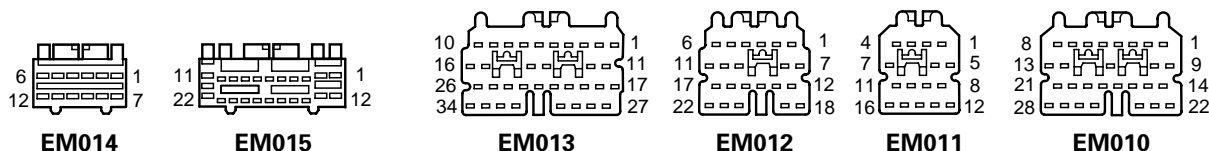
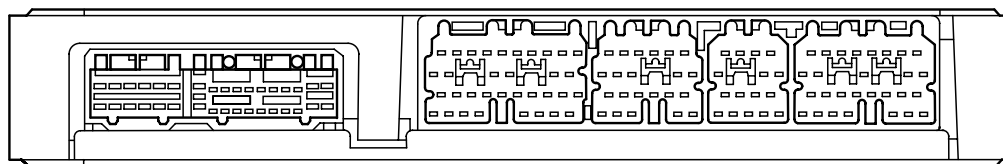
## Inputs and Outputs

Inputs and outputs are directed to and from the ECM through hard-wired connections and the CAN and ISO 9141/2 (Serial Communication) data buses contained in the engine management harness (for further information on the data buses, refer to the Technical Guide, XK8 1997 Model Year Introduction).

### ECM Pin Connections

Connector/ Pin    Circuit		Pin	Circuit	Pin	Circuit
<b>EM010</b>					
001	Ignition supply	012	ISO 9141/2	021	Sensor 5 V supply (accelerator
002	Load inhibit		(Serial Communication) in (L)		pedal position, mechanical
003	Windshield/Backlight heater request	013	ISO 9141/2		guard position and throttle position)
			(Serial Communication) out (K)	022	EGR ground
004	A/C clutch request	014	Parking brake switch	023	Signal ground 1
005	Ignition supply	015	Park/Neutral switch	024	Not used
006	OK to fuel (where incorporated)	016	EMS control relay	025	CAN in (-)
007	Not used	017	Security acknowledged	026	CAN in (+)
008	Not used	018	Not used	027	CAN out (-)
009	Battery supply	019	Not used	028	CAN out (+)
010	Brake switch (foot brake on)	020	Sensor ground (ECT, air intake temperature, accelerator pedal position, mechanical guard position and throttle position)		
011	Brake switch (cancel cruise control)				
<b>EM011</b>					
001	Cruise control set +/set - (acceleration/deceleration)	009	ECT sensor	014	Shield ground (accelerator pedal position, mechanical guard position and throttle position sensors)
002	Not used	010	Throttle position sensor 2		
003	ECM programming	011	Throttle position sensor 1	015	Accelerator pedal position sensor 2
004	Cruise control on/off	012	Sensor ground (ECT, air intake temperature, accelerator pedal position, mechanical guard position and throttle position)	016	Accelerator pedal position sensor 1
005	Cruise control resume/cancel				
006	Engine crank				
007	Not used	013	Mechanical guard position sensor		
008	Sensor 5 V supply (accelerator pedal position, mechanical guard position and throttle position)				
<b>EM012</b>					
001	EGR valve 1	009	Ignition failure amplifier 1	017	O2S A (where fitted)
002	EGR valve 2	010	A/C clutch relay	018	MAFS ground
003	EGR valve 3	011	Not used	019	MAFS ground
004	EGR valve 4	012	Air intake temperature sensor	020	Not used
005	A/C high pressure switch	013	MAFS	021	Not used
006	A/C low pressure switch	014	HO2S B	022	Shield ground (HO2S and O2S)
007	Not used	015	HO2S A		
008	Ignition failure amplifier 2	016	O2S B (where fitted)		

## ECM PIN CONNECTIONS



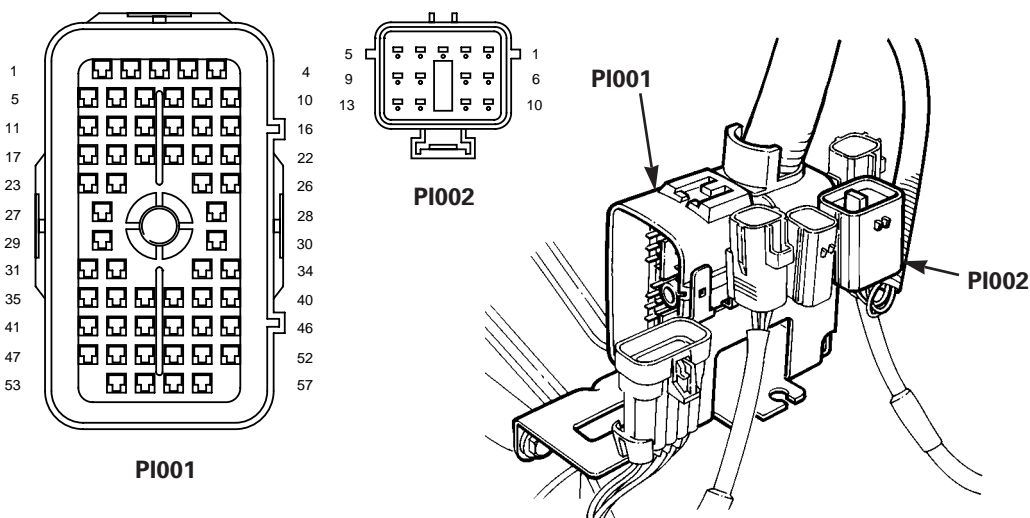
303-129

### Connector/

Pin	Circuit	Pin	Circuit	Pin	Circuit
<b>EM013</b>					
001	Fuel pump control	013	VSV 2	025	Ignition amplifier 2A
002	EMS programming	014	Throttle motor relay	026	Ignition amplifier 1A
003	Cruise control switch LED	015	Radiator cooling fans, slow	027	Shield ground (knock, engine speed and camshaft sensors)
004	)	016	Radiator cooling fans, fast	028	Engine speed sensor ground
005	)	017	Knock sensor B	029	Camshaft sensor ground
006	)	018	Knock sensor A	030	Not used
007	) Not used	019	Engine speed sensor	031	Ignition amplifier 4B
008	)	020	Camshaft position sensor	032	Ignition amplifier 3B
009	)	021	Not used	033	Ignition amplifier 2B
010	)	022	Ignition coil relay	034	Ignition amplifier 1B
011	VSV 3	023	Ignition amplifier 4A		
012	VSV 1	024	Ignition amplifier 3A		
<b>EM014</b>					
001	Throttle motor power	005	Throttle motor (+)	009	Valve timing ground
002	Throttle motor power	006	Throttle motor (+)	010	Power ground (miscellaneous)
003	Ignition supply	007	Throttle motor ground 2	011	Throttle motor (-)
004	Signal ground 2	008	Throttle motor ground 1	012	Throttle motor (-)
<b>EM015</b>					
001	HO2S B heater	009	Valve timing solenoid A	017	Injector 2A
002	HO2S A heater	010	Not used	018	Injector 1B
003	EVAP valve	011	Injector ground (1A, 2B, 3B, 4A)	019)	
004	Injector 3B	012	HO2S heaters ground	020)	Not used
005	Injector 2B	013	Not used	021)	
006	Injector 4A	014	Not used	022	Injector ground (1B, 2A, 3A, 4B)
007	Injector 1A	015	Injector 4B		
008	Valve timing solenoid B	016	Injector 3A		



## ENGINE HARNESS PIN CONNECTIONS



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## Engine Harness to Engine Management Harness Pin Connections

Connector/ Pin	Circuit	Pin	Circuit	Pin	Circuit
<b>PI001</b>					
001	Throttle position sensor 2	016	Valve timing solenoid A	036	Injector 2B
002	A/C compressor lock sensor ground	017	Knock sensor A	037	Injector 3B
003	Throttle position sensor 1	018	Screen ground (knock sensor A)	038	Injector 4B
004	Shield ground (throttle position sensor)	019	Knock sensor B	039	Ignition coil 4A
005	ECT sensor	020	Shield ground (knock sensor B)	040	Ignition coil 1A
006	Sensor ground (ECT, accelerator pedal position, mechanical guard position and throttle position)	021	Engine speed sensor ground	041	Ignition coil 3B
007	EGR valve 4	022	Engine speed sensor	042	Ignition coil 2B
008	EGR valve 1	023	Screen ground (engine speed sensor)	043	Ignition coil 4B
009	EGR valve 2	024	Camshaft position sensor ground	044	Ignition coil 3A
010	EGR valve 3	025	Camshaft position sensor	045	Ignition coil 2A
011	Generator regulator charge warning	026	Shield ground (camshaft sensor)	046	Ignition coil 1B
012	Mechanical guard position sensor	027	Valve timing solenoid B	047	EGR valve supply
013	A/C clutch	028	Valve timing solenoids and MAFS/intake air temperature sensor supply	048	Engine oil pressure sensor
014	Sensor 5 V supply (accelerator pedal position, mechanical guard position and throttle position)	029	Not used	049	Shield ground (accelerator pedal position and mechanical guard position sensors)
015	Not used	030	Injector 1A	050	Accelerator pedal position 1
		031	Intake air temperature sensor ground	051	Accelerator pedal position 2
		032	Injector 2A	052	MAFS
		033	Injector 3A	053	Ignition supply
		034	Injector 4A	054	MAFS ground
		035	Injector 1B	055	A/C compressor lock sensor
				056	MAFS ground
				057	Intake air temperature sensor

Connector/ Pin	Circuit	Pin	Circuit	Pin	Circuit
<b>PI002</b>					
001	)	006	Throttle motor (-)	011	Not used
002	) Not used	007	Throttle motor (+)	012	Generator regulator supply
003	)	008	)	013	Not used
004	)	009	) Not used		
005	Injector supply	010	)		

## CAN Messages

Messages on the CAN data bus used or output by the ECM are detailed below:

**Note:** This list does not include network monitoring or diagnostic related messages.

Message Used by ECM	Source/Used by	Message Produced by ECM
ABS MALFUNCTION FAST TORQUE REDUCTION CYLINDER FAST TORQUE REDUCTION IGNITION FRONT LEFT WHEEL SPEED FRONT RIGHT WHEEL SPEED REAR LEFT WHEEL SPEED REAR RIGHT WHEEL SPEED TORQUE REDUCTION THROTTLE TRACTION STATUS VEHICLE REFERENCE SPEED	Brake control module	BRAKE PEDAL PRESSED ENGINE MALFUNCTION ENGINE SPEED ESTIMATED ENGINE TORQUE PEDAL POSITION THROTTLE POSITION TRACTION ACKNOWLEDGE
FUEL LEVEL HEADLAMP HIGH BEAM STATUS HEADLAMP LOW BEAM STATUS SIDE LAMP STATUS	Instrument cluster	BRAKE PEDAL PRESSED ENGINE COOLANT TEMPERATURE ENGINE MALFUNCTION ENGINE SPEED FUEL USED PARK BRAKE STATUS THROTTLE MALFUNCTION AMBER THROTTLE MALFUNCTION RED
GEAR POSITION ACTUAL GEAR POSITION SELECTED GEAR SELECTION FAULT KICKDOWN STATUS TORQUE CONVERTER SLIP TORQUE CONVERTER STATUS TORQUE REDUCTION REQUEST TRANSMISSION INPUT SPEED TRANSMISSION MALFUNCTION TRANSMISSION OIL TEMPERATURE TRANSMISSION OUTPUT SPEED TRANSMISSION OVERLOAD	TCM	CRUISE CONTROL STATUS ENGINE SPEED ESTIMATED ENGINE TORQUE PEDAL POSITION THROTTLE POSITION TORQUE REDUCTION ACKNOWLEDGE

## Sensors

Engine management sensors that input to the ECM are detailed below:

### Barometric Pressure Sensor

The barometric pressure sensor is installed in the ECM. It senses ambient pressure in the engine management enclosure of the engine compartment.

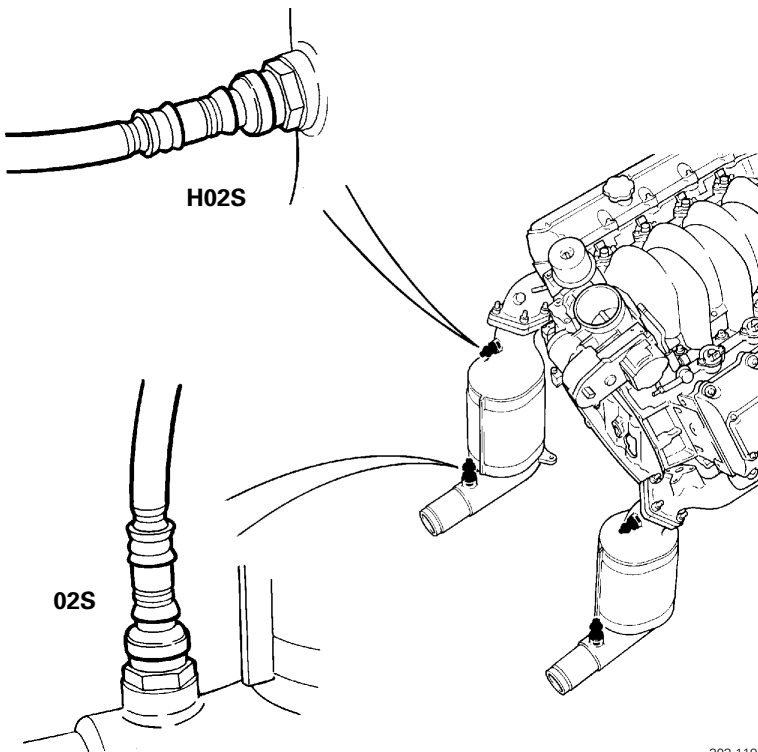
### HO2S

A HO2S is installed in the intake end of each catalytic converter. They provide inputs proportional to the oxygen content of the exhaust gases leaving the engine. The heater elements improve the response time of the sensors during engine warm-up.

### O2S

An O2S is installed in the outlet end of each catalytic converter. They provide inputs proportional to the oxygen content of the exhaust gases leaving the catalytic converter.

## OXYGEN SENSORS



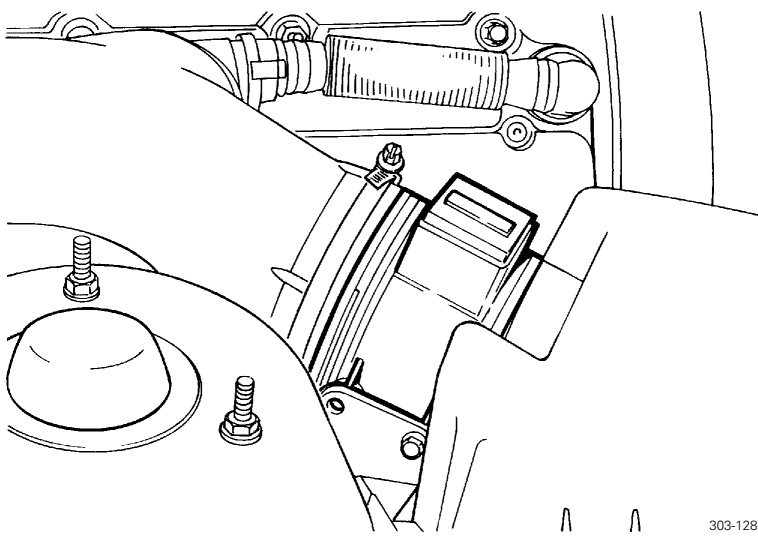
### Intake Air Temperature Sensor

The intake air temperature sensor is a thermistor integrated into the same housing as the MAFS, in the intake duct immediately downstream of the intake air cleaner. It provides an input inversely proportional to the temperature of the air in the duct.

### MAFS

The MAFS is a hot wire sensor that provides an input which is (approximately) proportional to mass air flow into the engine.

## MAFS/INTAKE AIR TEMPERATURE SENSOR



**Camshaft Position Sensor**

The camshaft position sensor is installed in B bank cylinder head at the rear of the intake camshaft. It is a variable reluctance sensor that provides an input of intake camshaft position.

**ECT Sensor**

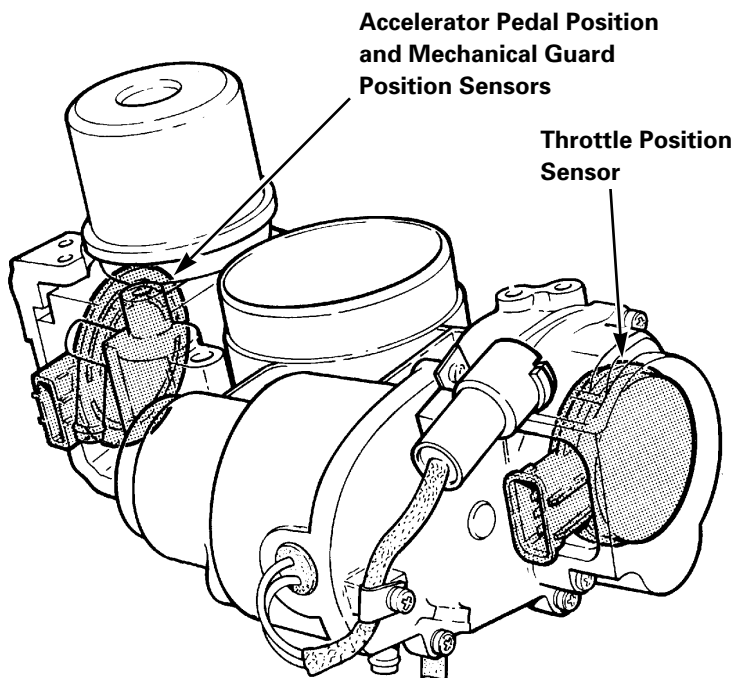
The ECT sensor is installed in the coolant outlet duct. It provides an input of coolant temperature at the cylinder head outlets.

**Engine Speed Sensor**

The engine speed sensor is installed at the rear of the bed plate. It is a variable reluctance sensor that provides an input of engine crankshaft speed and position.

**Knock Sensors**

The knock sensors are installed in the cylinder block on the inboard side of each cylinder bank. They are piezo-electric sensors that provide inputs to detect and locate detonation during combustion.

**ELECTRONIC THROTTLE SENSORS**

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**Accelerator Pedal Position Sensor**

The accelerator pedal position sensor is connected to the input shaft in the electronic throttle. It is a dual track potentiometer that provides inputs of driver demand at the accelerator pedal.

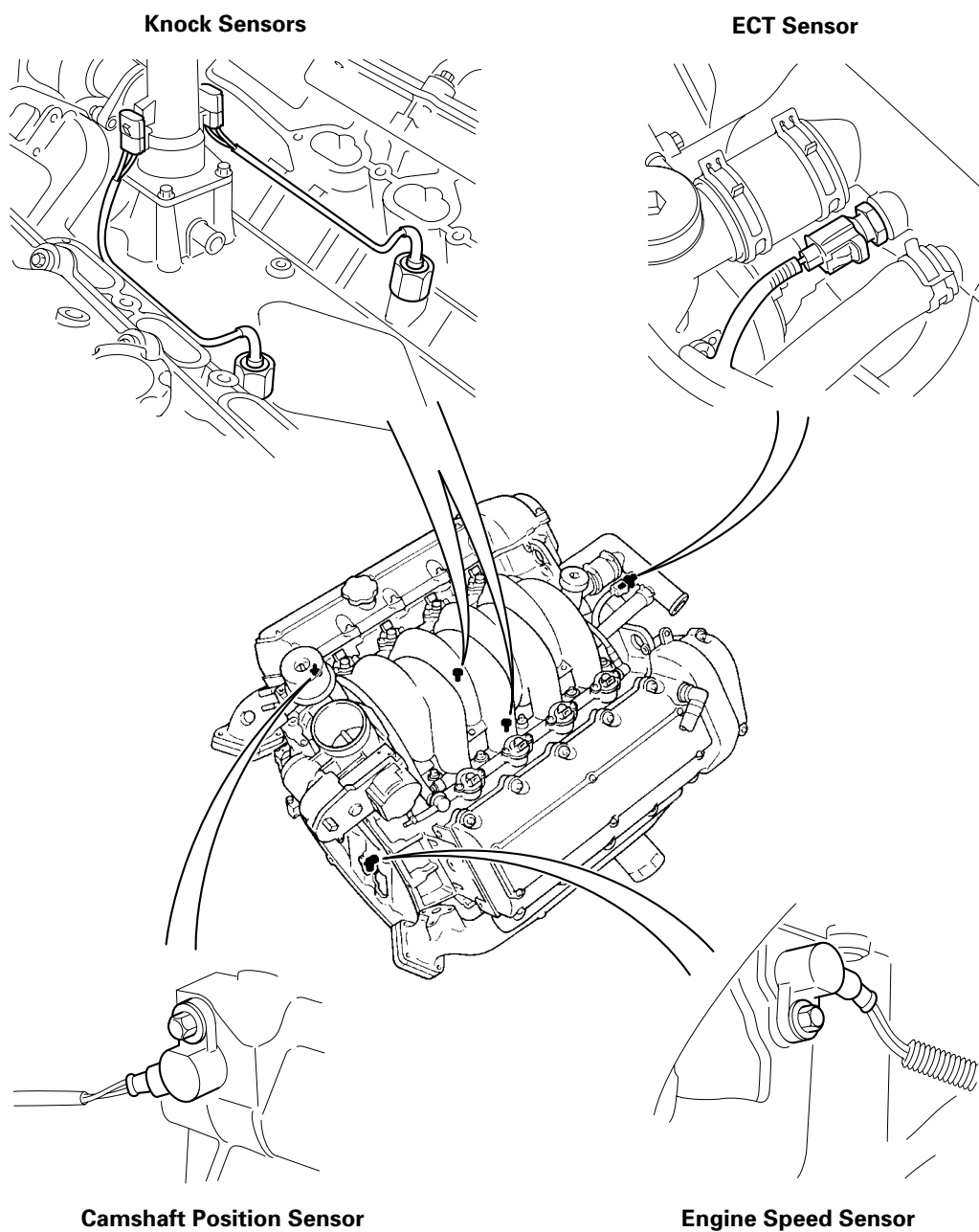
**Mechanical Guard Position Sensor**

The mechanical guard position sensor is a single track potentiometer connected to the mechanical guard in the electronic throttle. It provides an input of the position of the mechanical guard.

**Throttle Position Sensor**

The throttle position sensor is a dual Hall effect sensor in the motor end of the electronic throttle. It provides inputs of the position of the throttle valve.

**ENGINE SENSORS**

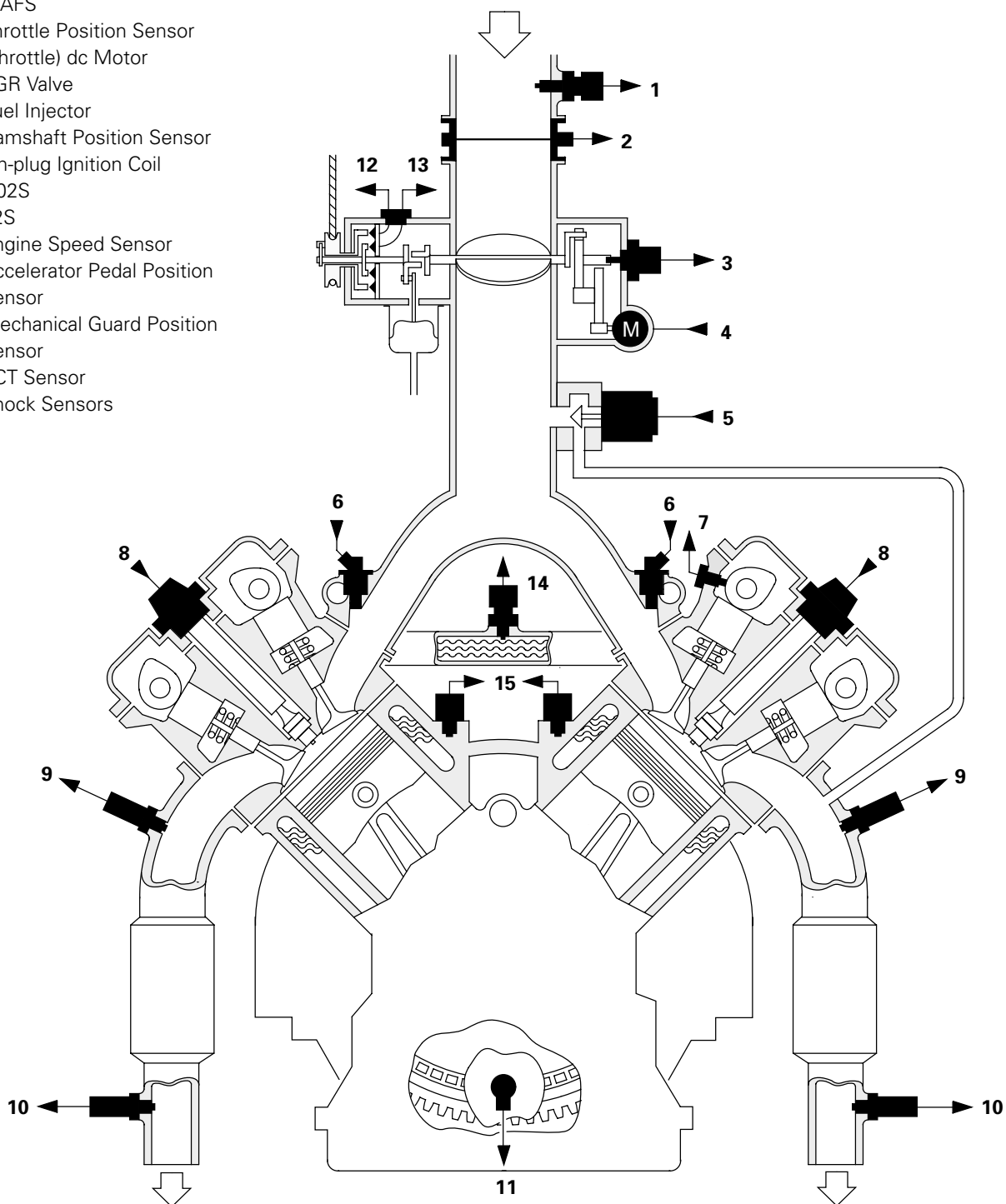


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## ENGINE MANAGEMENT SCHEMATIC

### ECM Inputs and Outputs

1. Intake Air Temperature Sensor
2. MAFS
3. Throttle Position Sensor
4. (Throttle) dc Motor
5. EGR Valve
6. Fuel Injector
7. Camshaft Position Sensor
8. On-plug Ignition Coil
9. H02S
10. O2S
11. Engine Speed Sensor
12. Accelerator Pedal Position Sensor
13. Mechanical Guard Position Sensor
14. ECT Sensor
15. Knock Sensors



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## Electronic Throttle

The electronic throttle enables the ECM to perform the following functions:

- engine air flow (ie. power) control
- engine idle speed control
- vehicle cruise control
- stability/traction control (in response to ABS commands)
- engine power limiting
- vehicle speed limiting
- reverse gear torque reduction

## Engine Air Flow Control

During normal operation, when the accelerator pedal is above idle, the ECM positions the throttle valve in response to the inputs from the accelerator pedal position sensor. The throttle valve follows or leads at a minimum distance the mechanical guard as the guard is moved by the accelerator pedal. Thus engine power output is directly related to driver demand. With the engine running, the time for the throttle to travel from idle to fully open is approximately 120 ms maximum, and from fully open to idle approximately 140 ms maximum.

## Idle Speed Control

During engine idle speed control, the ECM operates in a closed speed control loop to maintain a given target idle speed. The ECM uses gear selection, intake air temperature and battery voltage to determine the required target idle speed.

Gear selection is derived from the input of the Park/Neutral switch in the transmission rotary switch.

Battery voltage is monitored and, if low voltage is detected (11.8 V and below), target idle speeds are increased by up to 50 rpm to increase the output from the generator.

When the ECM selects a change of target idle speed, overshoot is kept to 50 rpm maximum.

Certain vehicle services/functions cause a significant change in engine load as they are selected on and off. To minimize the effect on idle speed, the ECM anticipates the change in load rather than correct the subsequent change in rpm. The services/functions the ECM anticipates load changes for are:

- A/C compressor clutch
- gear shifts between Park/Neutral and Reverse/Drive

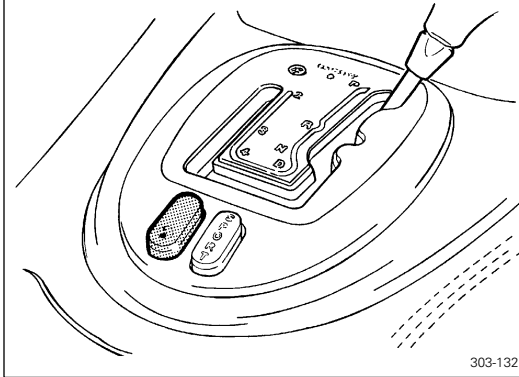
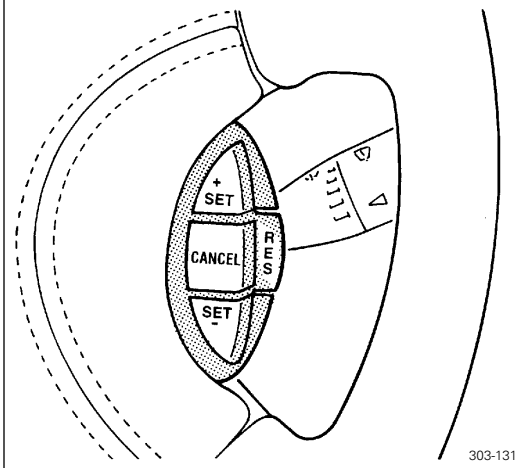
- headlamps and side lamps
- windshield and backlight heaters
- radiator cooling fans.

The ECM detects gear shifts, headlamp status and side lamp status from their related status messages on the CAN data bus. The ECM directly controls the A/C compressor clutch and the radiator cooling fans. The windshield and backlight heaters are controlled by the ACCM upon consent of the ECM via the heater request/load inhibit circuits.

If a fault develops in the idle control function, the ECM goes to open loop control. During open loop control, rpm is within +100 and -0 rpm of the target speed for a warm engine (ie. when the coolant temperature is >30 °C (86°F).

## Idle Target Speeds

Intake Air Temperature, °C (°F)	Engine Speed, (rpm)	
	Drive/Reverse	Park/Neutral
>-10 (14)	600 ± 25	650 ± 25
-10 to >-20 (14 to >-4)	625 ± 25	675 ± 25
-20 to >-30 (-4 to >-22)	650 ± 25	700 ± 25
≤-30 (≤-22)	675 ± 25	725 ± 25

**CRUISE CONTROL MASTER SWITCH**

**CRUISE CONTROL STEERING WHEEL SWITCHES**

**Vehicle Cruise Control**

The ECM operates the vehicle cruise control system, in all forward gears, in response to driver inputs through the master, **SET+**, **SET-**, **CANCEL** and **RES** switches.

When the master switch is pressed, two 12 V ignition supplies are connected to the ECM, one direct and one via the brake switch. The LED in the switch comes on to indicate the system is armed.

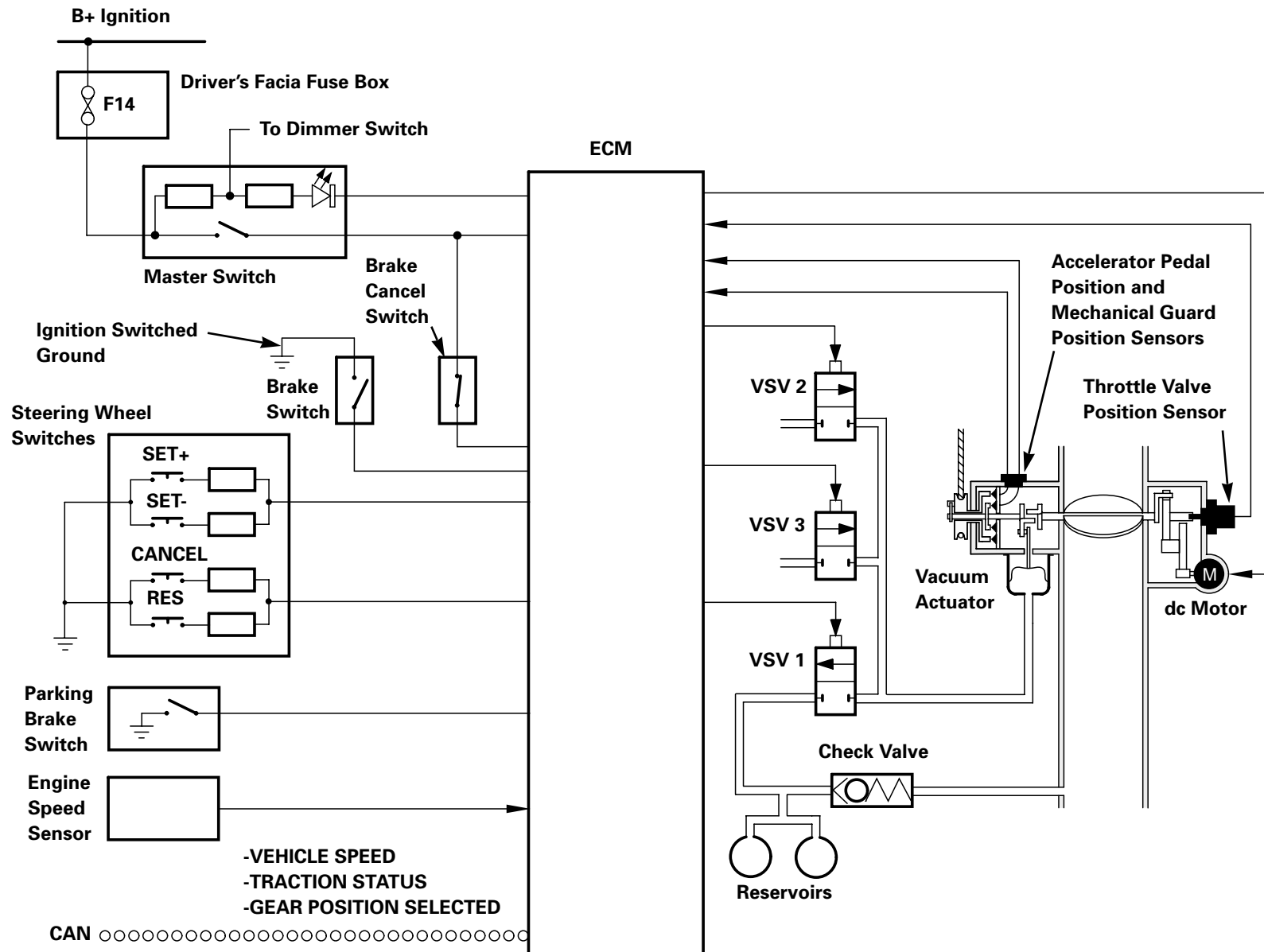
With the system armed, a momentary press of either the **SET+** or the **SET-** switch engages cruise control, provided the vehicle speed is 28 km/h (17.5 mph) or above. The ECM memorizes the current road speed as the 'set' speed and signals the vacuum system to operate the mechanical guard. The inputs from the position sensors in the electronic throttle allow the ECM to monitor and adjust the mechanical guard and the throttle valve to maintain the set speed.

The vacuum components are installed in a line connected between the induction elbow and the vacuum actuator on the electronic throttle. In the vacuum system:

- the check valve isolates the system from the induction elbow at wide open throttle when there is little or no vacuum available
- the reservoirs extend the time (to approximately 20 minutes) that, at wide open throttle, sufficient vacuum can be maintained in the system to operate the vacuum actuator
- VSV 1 regulates the vacuum applied to the vacuum actuator to control the position of the mechanical guard
- VSV 2 connects the vacuum actuator to atmosphere to release the mechanical guard when cruise control is disengaged
- VSV 3 is a back-up for VSV 2 (because cruise control disengagement is safety critical)
- filters on the atmospheric ports of VSV 2 and VSV 3 prevent moisture ingress.



# CRUISE CONTROL SCHEMATIC



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Once cruise control is engaged, a further momentary press of the **SET+** or **SET-** switch increments or decrements the set speed by 1.6 km/h (1.0 mph). The ECM then accelerates or decelerates the vehicle to the new set speed.

The ECM stores a maximum of five incremental or decremental commands at any one time. Once the ECM has actioned the first stored command, a further command can be added. On momentary operation of the opposite sense switch, the ECM deletes the last command from memory.

Pressing and holding the **SET+** or **SET-** switch causes the ECM to increase or decrease the set speed, and smoothly accelerate or decelerate the vehicle, until the switch is released. To protect against switch failure in the closed position, if either switch is held for longer than 10 minutes, the ECM disables cruise control until the next ignition cycle.

The throttle pedal can be used to accelerate the vehicle beyond the set speed, without disengaging cruise control (since the diaphragm actuator is holding the mechanical guard, there is a noticeable reduction in accelerator pedal load up to the point at which the input shaft in the electronic throttle begins to turn the mechanical guard). When the pedal is released the ECM returns the vehicle to the set speed in a controlled manner. Alternatively, a momentary press of the **SET+** or **SET-** switch causes the increased vehicle speed to be adopted as the new set speed.

On receipt of an input from the **CANCEL** switch, the ECM disengages cruise control and clears the set speed from memory. Disengagement is in a controlled manner to provide a smooth return of throttle control to the driver.

The ECM disengages cruise control, clears the set speed from memory and immediately returns control of the throttle to the driver if any of the following occur:

- the master switch is pressed, to switch the system off
- a fault is detected in the electronic throttle system, the brake switch or the cruise control switches
- the parking brake is applied
- the engine overspeeds.

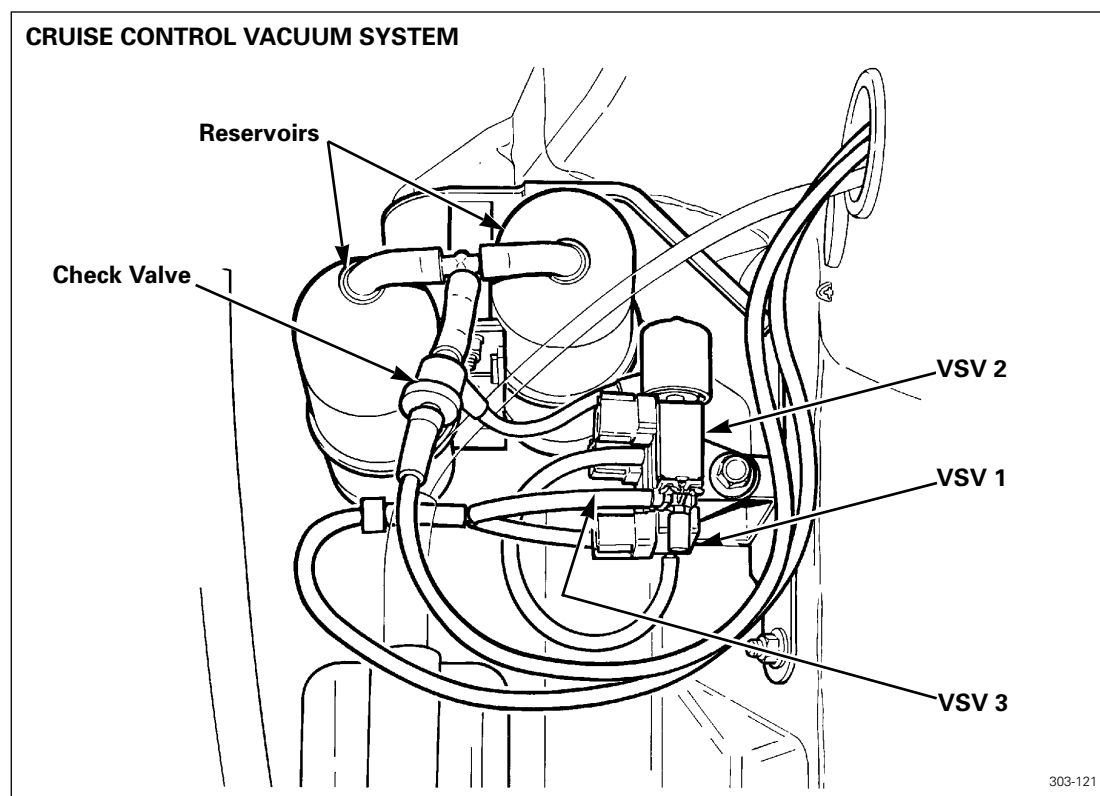
The ECM disengages cruise control, immediately returns control of the throttle to the driver and retains the set speed in memory, if any of the following occur:

- the brake pedal is pressed
- the vehicle decelerates too fast (ie. as under heavy braking, to guard against sticking contacts in the brake switch)
- the gear selector moves to neutral, park or reverse
- after resuming cruise control the vehicle accelerates to only 50% of the set speed (eg. due to a steep hill)
- the stability/traction control system operates
- vehicle speed decreases below 26 km/h (16 mph).

On receipt of an input from the **RES** switch, if a set speed is stored in the ECM memory, the cruise control function is re-engaged and the vehicle accelerated or decelerated to resume the set speed in a controlled manner.

The ECM continuously monitors the cruise control switches. If a switch fails closed, on the initial failure the input is treated as a driver command and the system responds accordingly. However, after subsequent disengagement then re-engagement of the system, the input from the failed switch is diagnosed as a fault. On detection of a switch fault, operation of cruise control is inhibited until the fault is corrected.

The ECM also conducts internal checking procedures to ensure that only permitted outputs are generated for given input conditions.



### Stability/Traction Control

If the CAN- TORQUE REDUCTION THROTTLE message from the brake control module requests torque reduction, the ECM reduces the throttle valve opening. It also changes the CAN- TRACTION ACKNOWLEDGE message to confirm that torque reduction is in progress.

### Engine Power Limiting

If the TCM detects a fault in the transmission, it changes the CAN- TRANSMISSION OVERLOAD message to request an engine torque limit. The ECM then limits throttle valve opening to 18° maximum in all forward gears.

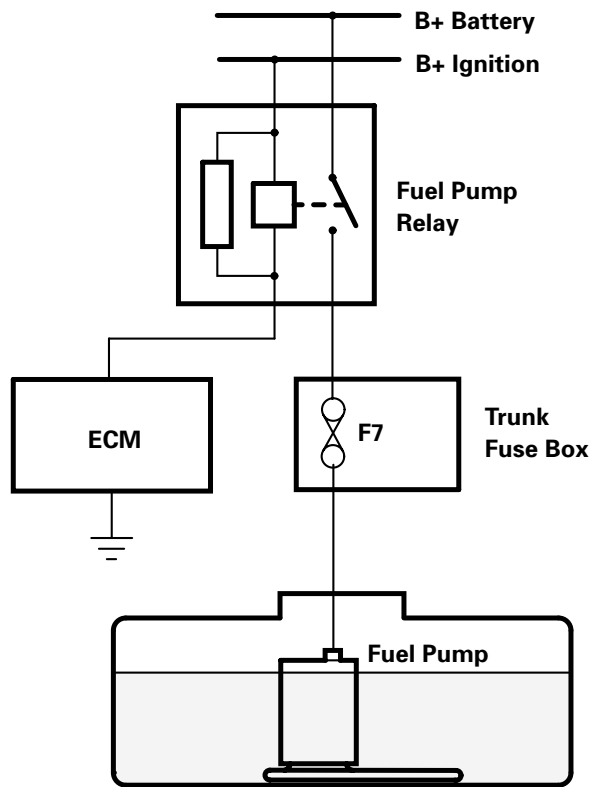
### Vehicle Speed Limiting

The ECM uses throttle control to limit the vehicle's maximum speed to 248 km/h (155 mph).

### Reverse Gear Torque Reduction

When reverse gear is selected the CAN- TRANSMISSION OVERLOAD message from the TCM requests an engine torque limit. The ECM then limits throttle valve opening to 18° maximum.

## FUEL PUMP CONTROL



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## Fuel Pump

An output from the ECM controls the relay that operates the fuel pump. At ignition on, the pump will operate for 2 seconds without the ignition switch being set to crank, after which time the pump will be de-energized. Similarly, if the engine stops with the ignition on, the pump will be de-energized after 2 seconds. The pump operates continuously while the ignition switch is set to crank, or to on with the engine running.

## Fuel Injection

The ECM operates eight injectors to provide the engine with fuel. The amount of fuel required is determined from a base air:fuel ratio which is then adjusted for specific operating conditions. The ECM varies the number and duration of injector pulses per engine cycle to regulate the fuel flow. Injector timing is synchronised with engine rotation, except during starting and acceleration.

Feedback signals from the two HO2S in the vehicle's exhaust system enable the ECM to exercise closed loop fueling control and adaptive fueling. Separate channels in the ECM control each bank of injectors.

Adaptive fueling accommodates engine efficiency variations, system tolerances and engine ageing. Adaptations are produced at idle speed and four other points through the RPM/load range, on a fully warm engine, when the adaptive fueling function centralizes the feedback range. The ECM retains the adaptations in memory, for use in subsequent driving cycles. If the difference between the new and previous adaptations is excessive, a DTC is logged in the ECM memory. If the battery supply to the ECM is disrupted (eg. battery disconnection), the adaptations are lost from memory. On restoration of the battery supply, engine operation may be uneven until the adaptations are restored, especially at idle speed.

The two O2S in the vehicle's exhaust system provide inputs which enable the ECM to monitor the efficiency of the downpipe catalytic converters. These inputs also enable the ECM to modify the HO2S inputs, to optimise the life of the catalytic converters.

## Base Fuel Map

The ECM contains a base fuel map that corrects the base air:fuel ratio to the optimum mixture for a nominal engine throughout the engine speed and load ranges.

## Battery Voltage Correction

Fuel flow through the injectors changes with voltage, so the ECM monitors their supply voltage and compensates for any variation from the nominal.

### Starting

The fueling start strategy operates independent of accelerator pedal position or movement, with the exception of a wide open throttle. The ECM produces steady state running at the target idle speed within 2 seconds of firing, after an overshoot of 200 to 300 RPM maximum.

If the accelerator pedal demands a wide open throttle during cranking, the ECM disables fuel injection (and signals the throttle valve to the fully open position) to clear the fuel vapor from a "flooded" engine.

### Warm-up Enrichment

During engine warm-up, the ECM determines the fuel required from maps which modify an enrichment factor for coolant temperature, engine speed and load.

### Transient Fueling

During acceleration and deceleration, the ECM adjusts fueling to optimise the air:fuel ratio for exhaust emission, response and economy. This function operates over the full temperature range for all acceleration and deceleration rates.

### Full Load Enrichment

At full load, the ECM inhibits closed loop fueling and increases the fuel supply to enrich the air:fuel ratio. Full load is derived from throttle valve position and engine speed. The degree of enrichment is dependent on engine speed.

### Over-run Fuel Cut-off

When the throttle is closed at high engine speeds, the ECM disables fuel injection until the engine is at a lower speed. The speeds at which fuel injection is disabled and re-instated are mapped against coolant temperature.

On re-instatement the ECM uses a lean air:fuel ratio, to provide a smooth transition between the two states, which it then progressively returns to the nominal. The initial injector pulses are given a correction value to compensate for cylinder wall wetting. The ECM derives the air:fuel ratio for re-instatement from throttle valve position and engine speed.

During over-run fuel cut-off, operation of the EVAP valve, EGR valve (where fitted) and closed loop fueling are inhibited.

### Engine Overspeed Protection

The ECM disables fuel injection if engine speed reaches 7100 RPM. Fuel injection is re-instated when RPM falls to 7050.

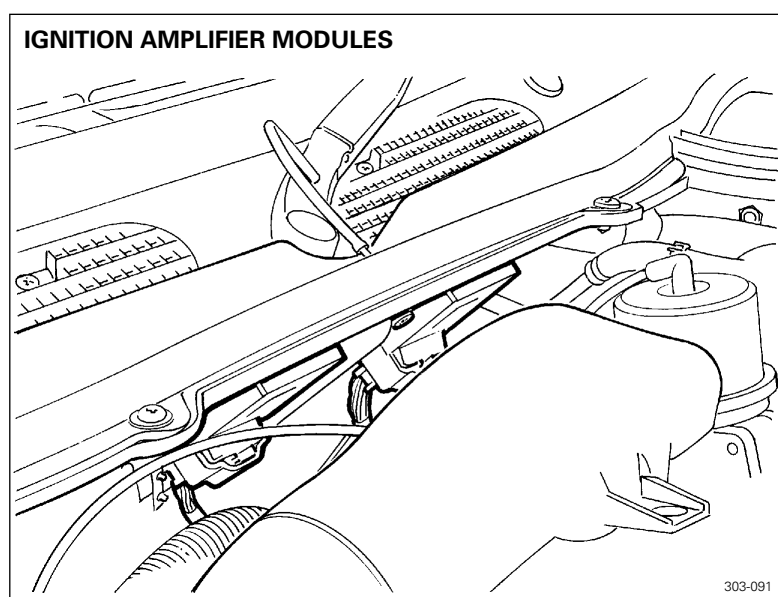
### Stability/Traction Control

If the CAN-FAST TORQUE REDUCTION CYLINDER message from the BCM requests fuel intervention, the ECM reduces engine torque by disabling fuel injection until the throttle valve reaches its required torque reduction position. It also changes the CAN-TRACTION ACKNOWLEDGE message to confirm that torque reduction is in progress.

## Ignition

The ECM supplies two ignition amplifier modules, which each supply four spark plug mounted ignition coils. The ECM varies the ignition timing to optimise power, emissions and driveability at all operating conditions.

A diagnostic signal from each amplifier module enables the ECM to monitor the supply to each ignition coil. If the ECM detects a failure it disables fuel injection to the affected cylinder.



**Base Ignition Map**

A base ignition map contains optimum timing for a nominal engine throughout the engine speed and load ranges. Corrections are then added to adjust for specific operating conditions.

**Temperature Corrections**

Corrections are added to the ignition timing to compensate for variations in intake air temperature and engine coolant temperature.

**Knock Control**

Between 700 and 6800 RPM, the ECM retards the ignition timing of individual cylinders if it detects detonation. Also, during acceleration at critical load and speed conditions, the ECM retards the ignition timing to prevent the onset of detonation.

**Full Load Advance**

At full load, the ECM advances the ignition timing at the same time as fuel enrichment is applied. The degree of advancement is dependent on engine speed.

**Fuel Cut-off Interaction**

Immediately prior to over-run fuel cut-off, the ECM retards the ignition timing to provide a smooth transition between the two states. On fueling re-instatement the ECM progressively returns the ignition timing to the nominal.

Throttle valve position and engine speed determine the rate at which the timing is returned to the nominal.

**Starting**

The ECM incorporates separate timing values for starting.

**EGR**

The ignition timing is advanced while the EGR system is active. The degree of advancement is dependent on engine speed and load.

**Gear Shift Management**

When the TCM decides a gear shift is necessary, it requests a percentage torque reduction using the CAN - TORQUE REDUCTION REQUEST message. The ECM then retards the ignition timing sufficient to achieve the torque reduction requested. As the ECM retards the ignition, it

changes the CAN-TORQUE REDUCTION ACKNOWLEDGE message to the TCM to trigger the gear shift.

**Transient Interaction**

A correction is applied to the ignition timing during throttle transients. The correction is against rate of change for both opening and closing of the throttle.

**Stability/Traction Control**

If the CAN-FAST TORQUE REDUCTION IGNITION message from the BCM requests ignition intervention, the ECM retards the ignition by the amount requested until the throttle valve reaches its required torque reduction position. It also changes the CAN-TRACTION ACKNOWLEDGE message to confirm that torque reduction is in progress.

**EVAP System**

The ECM operates the EVAP valve to purge the fuel vapor from the carbon canister. Purge rates (ie. the amount the EVAP valve opens) are a function of engine operating conditions and the vapor concentration level.

The engine operating conditions that affect the purge rate are:

- speed and load
- coolant temperature
- time from start-up
- closed loop fueling.

To determine the vapor concentration level, the ECM applies stepped opening signals to the EVAP valve and monitors the subsequent fueling correction. This is usually performed prior to purging, so that when purging starts, the EVAP valve can immediately be set to the optimum position. If the ECM is unable to determine the vapor concentration before purging, it uses a default value which it then modifies while purging is in progress. During purging, the ECM applies a correction to the basic fueling calculation based on the vapor concentration level.

Purging is inhibited during fuel cut-off and stability/traction control fueling intervention.

## Variable Valve Timing

The ECM energizes the valve timing solenoids to advance the intake valve timing and de-energizes them to retard it.

The ECM uses engine load and speed maps to decide when to advance and retard the timing. The maps incorporate hysteresis for both engine load and speed to prevent "hunting".

Between 1250 and 4500 RPM (nominal), at engine loads greater than approximately 25 % of the maximum, the timing is advanced. At low engine loads and at the two ends of the RPM range, the timing is retarded.

System operation is inhibited at engine coolant temperatures below  $-10^{\circ}\text{C}$  ( $14^{\circ}\text{F}$ ). System operation is monitored using the input from the camshaft position sensor. If a fault is detected the ECM defaults to the retarded (de-energized) condition.

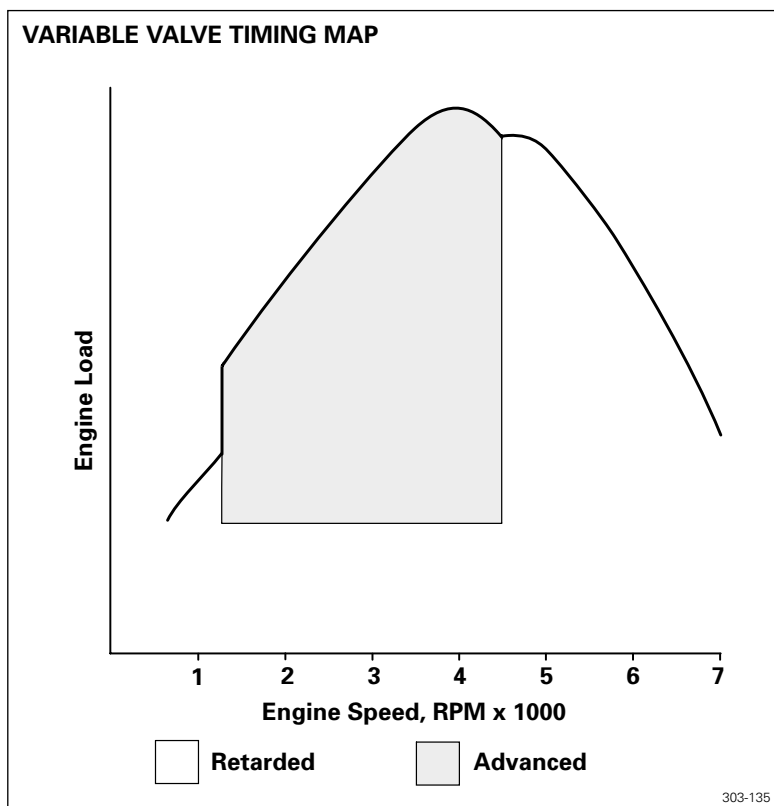
## EGR System

The ECM operates the 4 pole stepper motor in the EGR valve to control the recirculation of exhaust gases. Unlike previous systems, there are no temperature or position feedback signals from the valve. The ECM monitors EGR operation using changes of mass air flow.

## Engine Starting

At ignition on, if the gear selector is in Park or Neutral, the ECM enables the fuel injection and ignition functions. It also outputs a hard wired digital security acknowledge signal to the BPM to enable engine cranking. While the engine cranks, the BPM outputs a hard wired digital engine cranking signal to the ECM, which employs engine starting strategies for the duration of the signal.

If the gear selector is not in Park or Neutral at ignition on, the ECM inhibits the fuel injection and ignition functions, and withholds the security acknowledge signal to prevent cranking.



## H02S Heaters

The ECM energizes the heater elements of the HO2S during engine warm-up to shorten the time it takes for them to produce accurate outputs.

## Instrument Cluster

The instrument cluster uses CAN messages from the ECM to operate the trip computer, tachometer, engine coolant temperature gauge and the BRAKE, CHECK ENG and general warning lamps.

**Note:** The CHECK ENG lamp is commonly known as the MIL.

## A/C Compressor Clutch

Operation of the A/C compressor clutch is controlled by the ECM, to prevent unnecessary loads on the engine during unfavorable operating conditions.

On receipt of an A/C request signal from the A/CCM, the ECM immediately energizes the A/C compressor clutch relay provided the engine is not at idle speed, the coolant temperature is not above 119°C (246°F) and the throttle valve is not fully open. When the A/C compressor clutch relay energizes, the relay output is sensed by the A/CCM, confirming that the A/C compressor clutch is engaged.

If the engine is at idle speed, the coolant temperature is above 119°C (246°F) or the throttle is fully open, the ECM outputs a load inhibit signal to the A/CCM and delays energising the A/C compressor clutch relay. At idle speed the delay is only momentary (in the order of 50 ms) while idle speed compensation is implemented, after which the load inhibit signal is removed. At coolant temperatures above 119°C (246°F) or with a fully open throttle, the delay is for the duration of the inhibiting condition.

Similarly, with the A/C compressor clutch relay already energized, if the engine coolant temperature exceeds 119°C (246°F) or the throttle goes to fully open, the ECM de-energizes the A/C compressor clutch relay and outputs the load inhibit signal to the A/CCM until the inhibiting condition is removed.

## Windshield and Backlight Heaters

When the windshield heaters and/or the backlight heater are requested on, the A/CCM sends a screen request signal to the ECM. Provided the engine is not at idle speed, the coolant temperature is not above 119°C (246°F) and the throttle valve is not fully open, the ECM takes no action and the A/C control module subsequently energizes the heaters.

If the engine is at idle speed, the coolant temperature is above 119°C (246°F) or the throttle is fully open, the ECM outputs the load inhibit signal (the same one as used for the A/C compressor clutch operation) to the A/CCM to delay energising the heaters. At idle speed the delay is only momentary while idle speed compensation is implemented, after which the load inhibit signal is removed. At coolant temperatures above 119°C (246°F) or with a fully open throttle, the delay is for the duration of the inhibiting condition.

Similarly, with the heaters already energized, if the engine coolant temperature exceeds 119°C (246°F) or the throttle goes to fully open, the ECM outputs the load inhibit signal to the A/CCM and the heaters are de-energized until the inhibiting condition is removed.

## Radiator Cooling Fans

The ECM monitors inputs from the A/C single and triple pressure switches, and from the ECT sensor on the engine, to control the operation of the two radiator cooling fans. Outputs from the ECM control two relays contained in the radiator fans module, to operate the fans in off, slow or fast mode. In the slow mode the fans are connected in series; in the fast mode the fans are connected in parallel. Hysteresis in the temperature and pressure switching values prevents "hunting" between modes.



To counteract the increase in engine coolant temperature that occurs after the engine stops, at ignition off:

- if the fans are already on, the ECM keeps them on for 5 minutes, or until the ECT decreases to a pre-determined value, whichever occurs first
- if the fans are off, the ECM determines, from ECT and intake air temperature inputs, if the fans need to be switched on. If they do, it switches them on for 5 minutes, or until the ECT decreases to a pre-determined value, whichever occurs first.

## Radiator Fan Switching Points

Mode	Coolant Temperature, °C (°F)		A/C System Pressure, Bar (psi)	
	On	Off	On	Off
Slow	90 (194)	86 (187)	12 (174)	8 (116)
Fast	97.5 (207.5)	93.5 (200.5)	22 (319)	17.5 (254)

## Diagnostics

The ECM performs self test routines and monitors engine functions, inputs and outputs to ensure correct operation of the engine and the engine management system. Hard wired inputs and outputs are monitored for short and open circuits, and sensor inputs are also monitored for range.

Additional checks are run on the more critical sensor inputs to ensure their validity. Some of the more critical inputs have substitute or default values which the ECM adopts if the input is diagnosed as faulty.

Any faults detected are logged in the ECM memory as DTC. The ECM also outputs engine malfunction messages on the CAN and adopts a default mode of operation. Most default modes retain some degree of engine operation (limp home).

The ECM also stores OBD II related DTC detected by other control modules on the CAN. Non-OBD II related DTC are retained in the memory of the control module that detects the fault.

To prevent false DTC being logged, the monitoring of some inputs and engine functions is inhibited while the vehicle is above a given altitude:

- at altitudes of 2438m (8000ft) and above, the ECM inhibits diagnostics on: EGR valve and EGR flow; EVAP valve and EVAP purge flow; idle speed control; misfire detection; catalytic converter efficiency.
- at altitudes of 2652m (8700ft) and above, the ECM also inhibits diagnostics on: HO2S; MAFS; O2S.

### Additional Input Checks

Input	Additional Strategy	Action, Substitute or Default Value
Accelerator pedal position (x 2) and mechanical guard position	Accelerator pedal position input 1 compared to accelerator pedal position input 2. Both accelerator pedal position inputs compared to mechanical guard position input.	If one input fails, the input of the other two is used. If two inputs fail, ECM adopts fixed throttle mode.
Throttle position (x 2)	1 compared to input 2. Input 1 compared to target value (target value depends on operating mode, eg. normal running, cruise control, traction active).	If either input fails, ECM adopts mechanical guard mode of operation.
Engine coolant temperature	After engine start, checks that expected temperature increase occurs, then monitors for excessive temperature decrease.	If fault detected, uses substitute value derived from transmission oil temperature.
Mass air flow	Compares input with predicted air flow (derived from a map of throttle angle against engine speed).	If fault detected, uses throttle angle as load measurement.
Intake air temperature	Monitors for too fast change of input and for fixed input.	If fault detected, uses a fixed intake air temperature of 50°C (122°F).

### Default Modes

Mode	Effect	General Warning Lamp	CHECK ENG Lamp (MIL)	Message
Engine shutdown	Activates fuel cut-off to stop engine	Red	On	ENGINE FAULT
Fixed throttle	Fixed throttle valve angle of approximately 2.5° set, producing maximum engine speed (unloaded) of approximately 1200 RPM.	Red	On	ENGINE FAULT
Mechanical guard	Engine speed increases as throttle valve goes to mechanical guard position; idle speed increases to approximately 1400 RPM; full throttle available	Red	On	ENGINE FAULT
Engine speed limiting	Engine speed limited to 3000 RPM	Amber	On	ENGINE FAULT
Redundancy	Substitute or default value adopted; no noticeable difference in performance	Amber	Off	ENGINE FAULT
Exhaust emission	Substitute or default value adopted; potential difference in performance	None	On	None

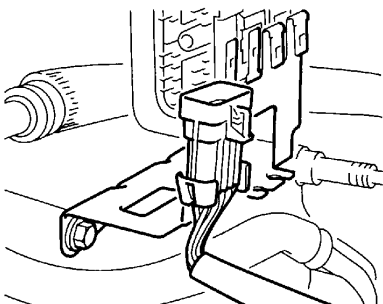
**Note:** In mechanical guard mode, fuel intervention smooths the transition from normal to default mode, to prevent sudden acceleration of the vehicle. Also, fuel intervention limits idle speed. Without fuel intervention idle speed would be approximately 2000 RPM and cause excessive shock loads on the transmission when shifting out of Park or Neutral. When engine load increases, idle speed fuel intervention is progressively withdrawn.

## Introduction

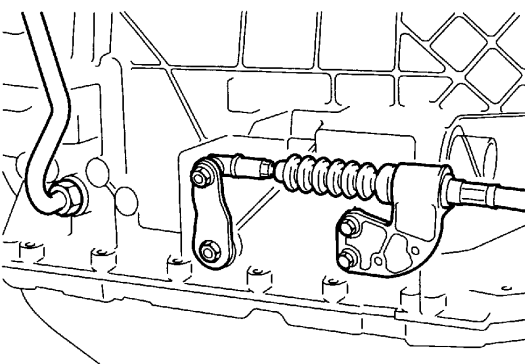
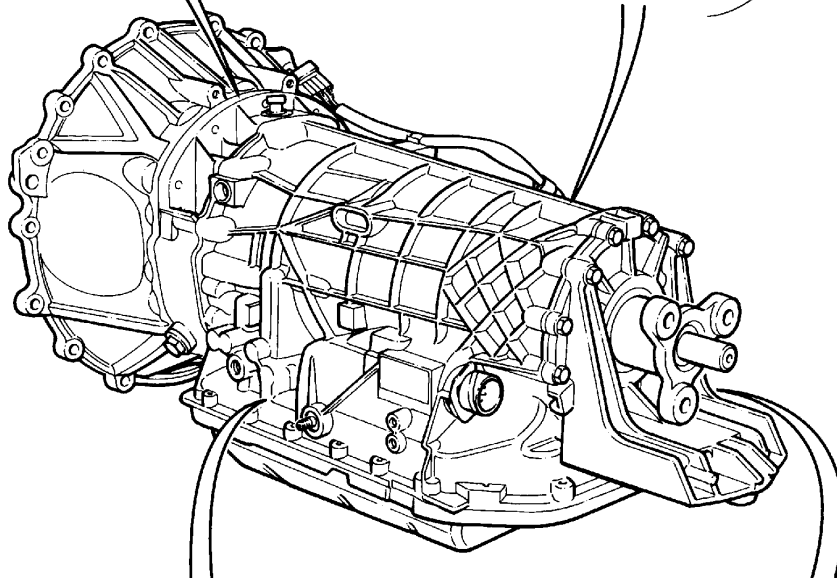
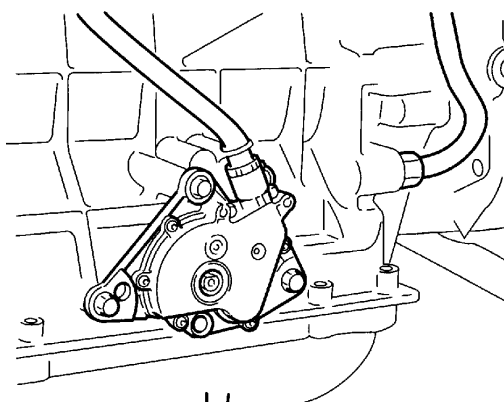
The new ZF 5HP24 automatic transmission system features five forward gears and one reverse gear. It also features a filled-for-life oil system. Gearshift management is achieved using a Transmission Control Module (TCM).

### TRANSMISSION

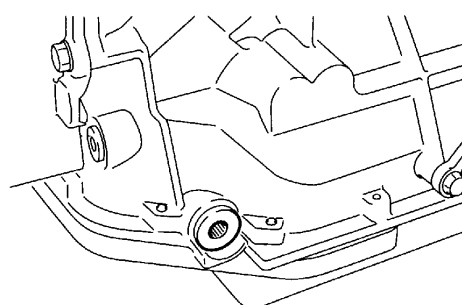
**Rotary Switch Connector**



**Rotary Switch and Oil Inlet Pipe**



**Oil Outlet Pipe and Selector Cable**



**Level/Filler Plug**

307-012

Tecnical Data

Transmission weight including fluid and torque converter	95.8 kg (211 lbs)
Oil Type	ATF Esso LT71141
Oil Capacity	10 liters (2.645 US. gals)
Gear Ratios	1st Gear 3.571:1
	2nd Gear 2.202:1
	3rd Gear 1.505:1
	4th Gear 1.000:1
	5th Gear 0.803:1
	Reverse 4.095:1

Gearshifting

Driver gear selection is transmitted from the gear selector lever by cable to a lever fitted to a selector shaft in the transmission casing. This shaft moves the manual valve and the rotary switch. The rotary switch signals all gear positions except D to 4. A separate switch in the driver gear selector mechanism detects movement of the selector between D and 4. The communication of driver gear selection to the TCM is made by the rotary switch. Gear shift points are selected by the TCM in response to output speed, engine load, selector position, accelerator pedal position and driver mode selection. Driver control of the shifting is via the selector lever, throttle pedal position, kickdown switch and mode switch. Two shift modes are available, sport and normal, controlled by the driver from a switch on the gear selector surround. During kickdown, gear upshifts occur at 6800 RPM engine speed.

Mechanical Description

The unit is an oil filled-for-life system therefore no dipstick is fitted to the transmission. A filling/level plug is located at the right-hand side rear of the casing for service oil level checking and replenishment, if required. To achieve effective cooling, the oil is pumped from the transmission casing at the front left-hand side of the casing to the car mounted oil cooler. The oil is returned from the cooler to the inlet connection on the front right-hand side of the casing. The cooler is a plate-type design made from aluminum and is located in the car radiator outlet tank. To detect changes in oil viscosity which occur as the oil temperature changes, an oil temperature sensor is located in the unit casing sump. Also located

in the transmission casing are the input shaft speed sensor (turbine speed) and output shaft speed sensor (vehicle speed). The torque converter is a lightweight unit which, because of its low mass, improves engine responsiveness. The torque converter bell housing is bolted to the transmission casing. Mounting of the transmission is conventional by bolting the torque converter bell housing to the engine. The rear extension housing is bolted to the transmission casing and forms the rear engine/transmission mounting point. It also carries the output shaft oil seal.

The electro-hydraulic module contains three solenoid valves and five pressure regulators for gear shifting. Each of the three solenoid valves control the flow of transmission fluid to the selected clutches. One pressure regulator serves as master pressure control for the entire system and one is used exclusively for torque converter clutch lock-up operation.

Replacement transmission units are shipped complete with the torque converter and housing, extension housing, coupling flange and rotary position switch. They are also fully filled with 10 liters (2.645 US. gals) of oil. Consequently, when undertaking a transmission replacement, oil replenishment should not be necessary. The exterior of the transmission is coated with a non-drip corrosion protection oil, which must not be

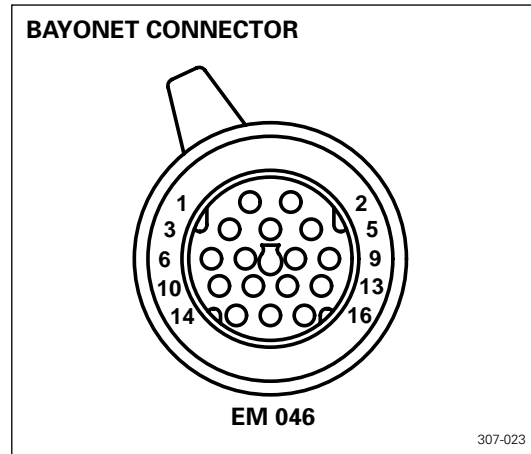
## Electrical Description

mistaken for an oil leak.

### Electrical Connections

#### Bayonet Connector

A round, 16-pin, bayonet electrical connector is fitted at the rear left-hand side of the transmission which communicates with the 5 pressure regulators, 3 shift solenoids, oil temperature sensor and the input and output



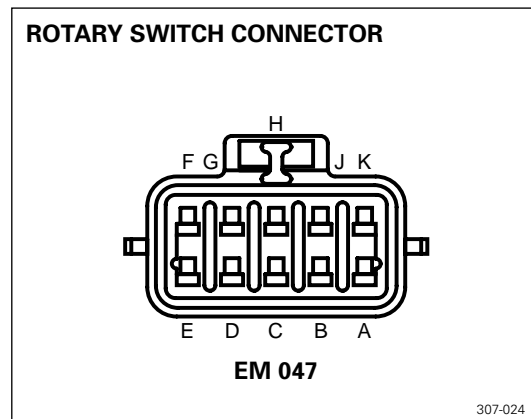
#### Connector/

Pin	Circuit	Pin	Circuit	Pin	Circuit
shaft speed sensors.					
<b>EM046</b>					
001	Output Speed Sensor (+)	006	Turbine Speed Sensor (-)	012	Solenoid Valves (+)
002	Pressure Regulator 1	007	Pressure Regulator 3	013	Analog Ground
003	Pressure Regulator 2	008	Shift Solenoid 1	014	Oil Temperature Sensor
004	Shift Solenoid Valve 3	009	Shift Solenoid 2	015	Pressure Regulator 5
005	Turbine Speed Sensor (+)	010	Output Speed Sensor (-)	016	Regulator (+)
		011	Pressure Regulator 4		

#### Rotary Switch Connector

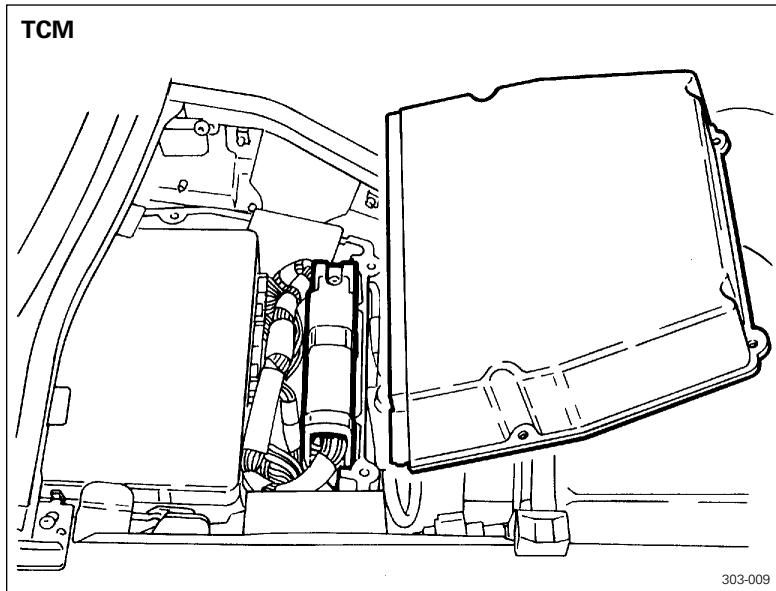
The rotary switch, mounted on the right-hand side of the casing, has a spline arrangement which prevents misalignment with the selector shaft. A locating pin and two bolts secure the rotary switch to the transmission casing. This locates the switch with the transmission casing and the shaft in one place only. The switch requires no other setting up procedure.

A 10-way connector with flying lead connects the rotary switch to the engine management harness. The connector is retained on a multi-connector bracket bolted to the transmission casing/torque converter housing joint.



#### Connector/

Pin	Circuit	Pin	Circuit	Pin	Circuit
<b>EMO47</b>					
00A	Position L1	00E	Digital Ground	00J	12V Power Supply
00B	Position L2	00F	Not Used	00K	Park & Neutral Switch
00C	Position L3	00G	Not Used		
00D	Position L4	00H	Not Used		



## Transmission Management

The transmission management system uses both analogue and digital signals, to control the operation of the transmission. Digital signals are processed by the TCM to and from the vehicle multiplex network. Other input/output analogue signals are hardwired to the TCM. This information is used primarily by the TCM to decide which shift program to implement, which gear to select and for shift energy management. If a fault occurs, the TCM will take default action and inform the driver via the Message Centre and amber warning light.

### Harness Connector

The vehicle harness connector for the TCM is an 88-way latching connector. The TCM is wired to the electrical pressure regulators/solenoids, oil temperature sensor and shaft speed sensors in the transmission casing.

### Sport Mode

When sport mode is selected by the driver using the mode switch, the sport pattern is only activated when a set cornering force is achieved, or the kickdown switch is pressed. The vehicle speed and the difference in speeds between the two front wheels is used to calculate the amount of cornering force.

### Torque Converter Lock-up

The torque converter lock-up clutch is engaged as a function of throttle position, output speed, oil temperature, gear shift and shift program. Lockup is possible in 2nd, 3rd, 4th and 5th gears but is usually restricted to 4th and 5th gears. During a gear shift the TCM controls the amount of slip of the lock-up clutch to enhance shift quality.

### Oil Temperature

When the engine coolant or transmission oil temperature exceeds set thresholds a hot mode program is selected which locks the torque converter clutch, minimising the amount of heat entering the engine cooling system from the transmission oil.

**Gear Shift Interlock**

Gear shift interlock is controlled by the BPM, part of the SCP network. The gearshift release will only be activated when the ignition is in position II, transmission is in Park and the brake pedal is depressed. Once transmission is out of Park, the brake pedal has no effect on gearshifting and the interlock is disabled.

**Reverse Inhibit**

Selection of reverse with the vehicle moving forwards above walking pace is electrically inhibited, unless the vehicle is in the default "limp-home" mode.

**Kickdown**

A floor mounted switch/pedal position sensor signals the TCM to select the lowest gear to give maximum torque for acceleration.

**Torque Control**

The TCM synchronises the operation of the transmission clutches and invokes shift energy management to control engine output torque during a gear shift (Refer to EMS, page 60).

**Traction Mode**

The traction program compliments the traction control system and is implemented whenever traction control intervenes to maximize wheel stability.

**Cruise Mode**

Cruise mode reduces unwanted hunting of the transmission gearshifting and is activated when cruise control is resumed and when the vehicle is cruising near the set speed.

**Gradient Mode**

The gradient program enhances vehicle performance, driveability and cooling when the vehicle is climbing a gradient.

**Start Inhibit**

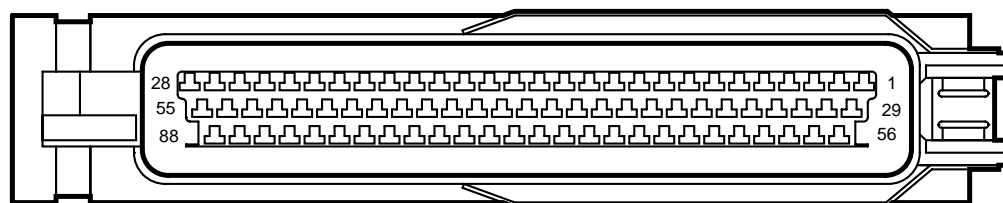
The rotary switch also provides the start inhibit function to the ECM, which will not allow an engine start until the gear selector is in either Park or Neutral.

**Fault Monitoring/Diagnostics**

The TCM constantly monitors the transmission system for faults. In the event of a fault occurring, the transmission is protected by a limp home mode. This mode allows use of P, R, N, and 4. It also signals the ECM to switch on the CHECK ENG (MIL) lamp.

The TCM is able to diagnose faults in components which affect exhaust emissions. Communication with the PDU is through the J1962 connector which allows accurate diagnosis of transmission problems. Additional diagnostic functions facilitate fast repair of faults. All transmission OBDII information is stored for future data analysis in the ECM.

TCM



EM 007

307-022

## Transmission Control Module Pin Connections

Connector/  
Pin Circuit

Pin Circuit

Pin Circuit

### EM007

001	Pressure Regulator 2	023	Shield (Input Speed Sensor)	045	Mode Switch Pin A
002	Mode Switch Illumination	024	Not used	046	)
003	Not used	025	Not used	047	Not used
004	Pressure Regulator 4	026	Battery Feed	048	)
005	Pressure Regulator 1	027	Not used	049	)
006	Power Ground	028	Digital Ground	050	)
007	Not used	029	Pressure Regulator 3	051	Pressure Regulator 5
008	Position Switch L2	030	Shift Solenoid 1	052	Solenoid valve + ve
009	Position Switch L4	031	Not used	053	Pressure regulator + ve
010	Not used	032	Shift Solenoid 3	054	Fused Ignition + ve
011	Not used	033	Shift Solenoid 2	055	Fused Ignition + ve
012	Mode Switch Pin B	034	Power Ground	056	
013	Drive to Fourth Switch	035	Not used	to	
014	Turbine Speed (-)	036	Position Switch L1	081	Not used
015	Shield (Output Speed Sensor)	037	Position Switch L3	082	CAN Link In - ve
016	Output Speed (+)	038	)	083	CAN Link In + ve
017	Not used	039	Not used	084	CAN Link Screen
018	Kickdown Switch	040	)	085	CAN Link Out - ve
019	Not used	041	)	086	CAN Link Out + ve
020	Not used	042	Turbine Speed (+)	087	Not used
021	Analogue Ground	043	Not used	088	Not used
022	Oil Temp Sensor	044	Output Speed (-)		



### Can Messages

Messages on the CAN data bus used or output by the TCM are detailed below:

**Note:** This list does not include network monitoring or diagnostic related messages.

Message Used by TCM	Source/Used by	Message Produced by TCM
TRACTION STATUS ABS STATUS FRONT LEFT WHEEL SPEED FRONT RIGHT WHEEL SPEED	Brake Control Module	TRANSMISSION INPUT SPEED TRANSMISSION OUTPUT SPEED TORQUE CONVERTER SLIP KICKDOWN SWITCH GEAR POSITION ACTUAL TORQUE CONVERTER STATUS TRANSMISSION SHIFT MAP TRANSMISSION MALFUNCTION TRANSMISSION FAULT CODES
	Instrument Cluster	GEAR POSITION ACTUAL GEAR POSITION SELECTED TRANSMISSION OIL TEMPERATURE TRANSMISSION MALFUNCTION
ESTIMATED ENGINE TORQUE THROTTLE VALVE POSITION ACCELERATOR PEDAL POSITION TORQUE REDUCTION ACKNOWLEDGE ENGINE SPEED CRUISE STATUS BRAKE PEDAL DEPRESSED ENGINE COOLANT TEMPERATURE ENGINE MALFUNCTION	ECM	TORQUE REDUCTION REQUEST TRANSMISSION OVERLOAD TRANSMISSION INPUT SPEED TRANSMISSION OUTPUT SPEED TORQUE CONVERTER SLIP KICKDOWN SWITCH GEAR POSITION ACTUAL TORQUE CONVERTER STATUS GEAR POSITION SELECTED TRANSMISSION SHIFT MAP TRANSMISSION OIL TEMPERATURE TRANSMISSION MALFUNCTION TRANSMISSION FAULT CODES

## New Tools

The table below lists the new service tools required for the AJ V8 engine. These are in addition to the tools already in use on 6 and 12 cylinder engines, some of which can also be used on the AJ V8. Details of new service tools for the 5HP24 transmission will be supplied at a later date.

Part Number	Description
JD 215	Camshaft setting/locking tool
JD 216	Crankshaft setting/locking peg
JD 217	Timing chain tensioner tool
JD 218	Timing chain wedges (2 each)
JD 220	Dummy main bearing caps (5 each)
JD 221	Bore protector - connecting rod installation (2 each)
JD 222	Engine rear lifting brackets (1 pair)
JD 223	Engine stand mounting brackets (1 pair)
JD 229	Crankshaft rear oil seal remover/replacer
JD 230	Belt tensioner release tool
JD 231	Fuel injector remover
JD 232	Valve lifter hold-down tool
JD 233	Fan nozzle air gun
JD 234	Crankshaft front oil seal remover
JD 235	Crankshaft front oil seal replacer
MS 76-140-5	Valve seat 5 mm pilot (for use with existing MS 76 valve seat cutter tools)
18G 1437-2	Adapter (for use with existing front pulley lock tool 18G 1437)
-	Cranked 13 mm box wrench, for starter motor upper securing bolt (eg. Snap-on part number CXM 1113)
-	Spring band hose clamp pliers (eg. Snap-on part number HCP 20)
-	Torque/Angle disc, for yield tightening of bolts (eg. Snap-on part number TA 360)
-	Valve seal pliers (eg. Snap-on part number YA 8230)
-	24 mm, 0.375 inch drive, open wrench, for knock sensors (eg. Snap-on part number FCOM 24)
-	8 inch long, 0.375inch drive, angle extension, for use with 24 mm open wrench (eg. Snap-on part number FXW 8)